T2
163

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

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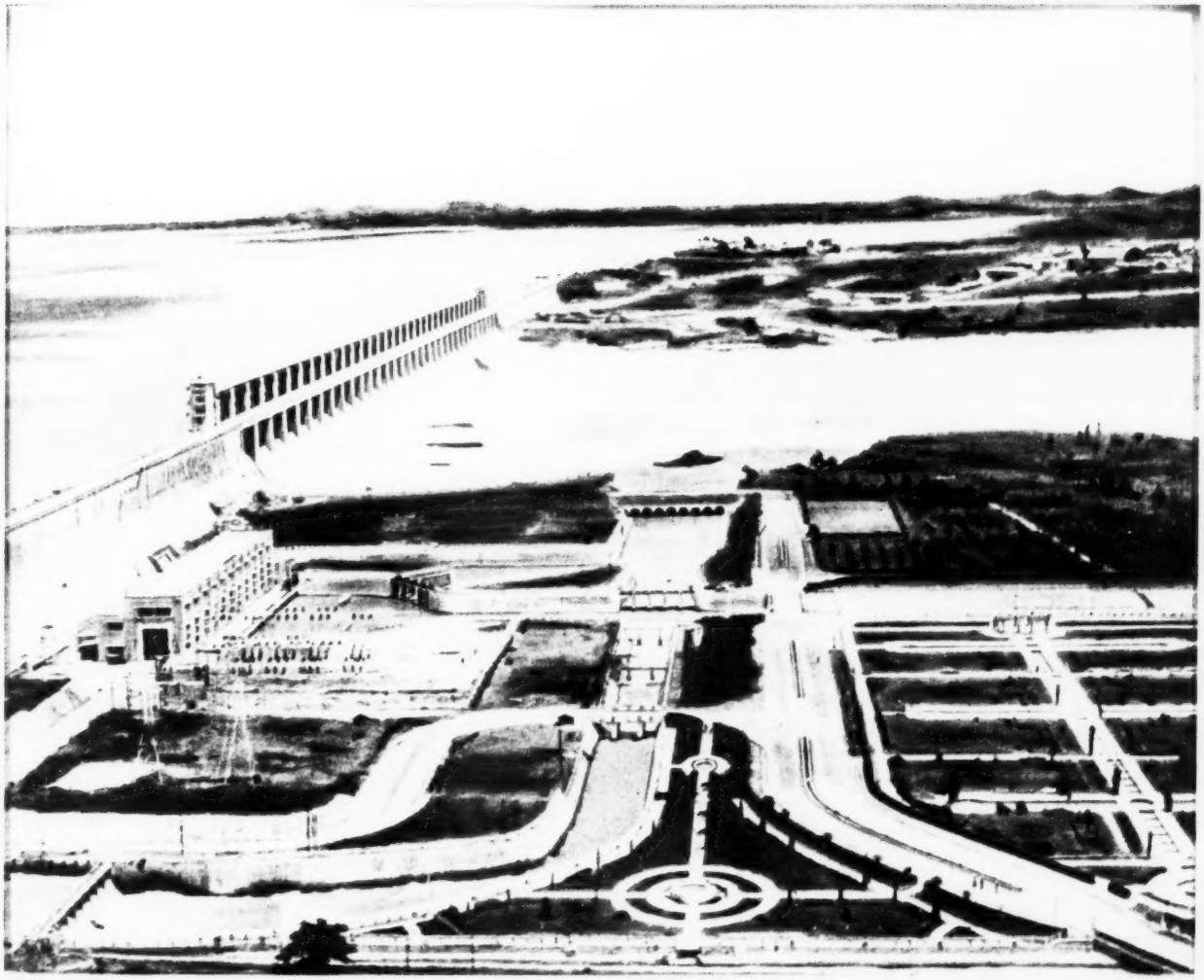
TUNGABHADRA PROJECT NUMBER

VOL. IX NO. 2 FEBRUARY, 1959 RUPEES THREE



A VIEW OF THE TUNGABHADRA DAM & POWER HOUSE

GE[redacted]ND PUTS IT TO WORK . . .

▼ 22,000 kVA Water-wheel generator being assembled for testing at Toshiba Tsurumi Works.

Casing for 133,000 kVA Water-wheel Generator. ▲

For nearly 90 years, all types of electrical equipment ranging from giant generator to tiny transistor have been manufactured by TOSHIBA. And so with the future, TOSHIBA will bring the latest advances in the field of electrical progress for happiness of all throughout the world.

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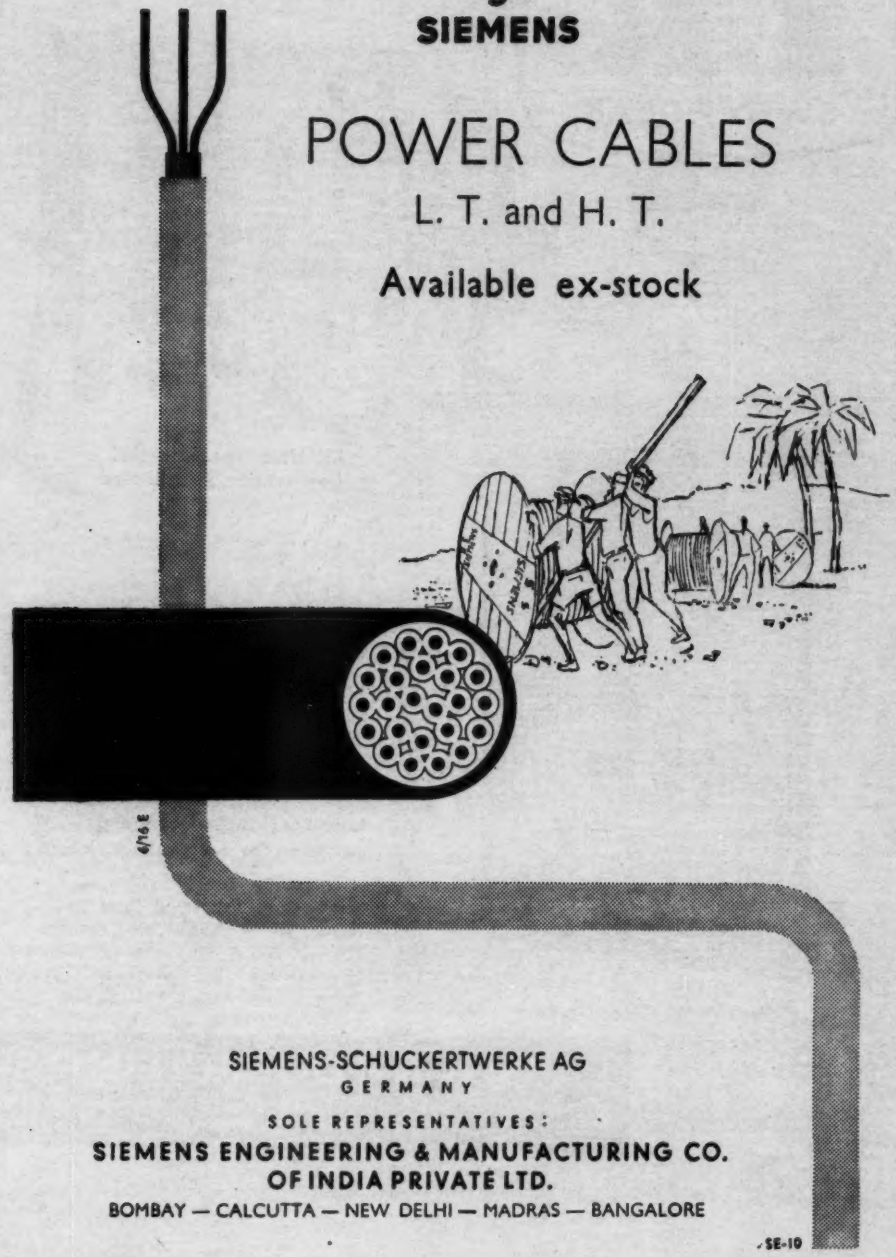

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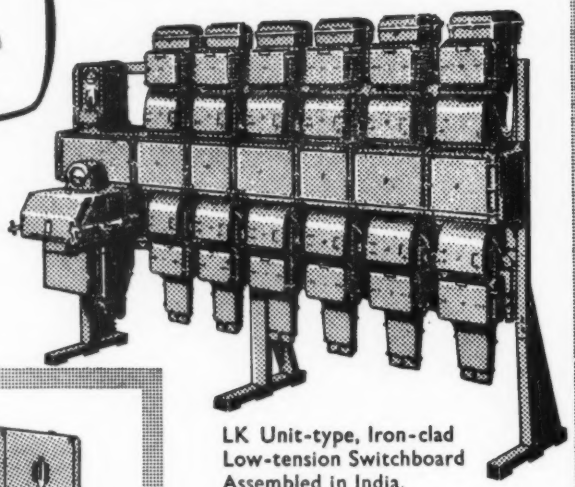
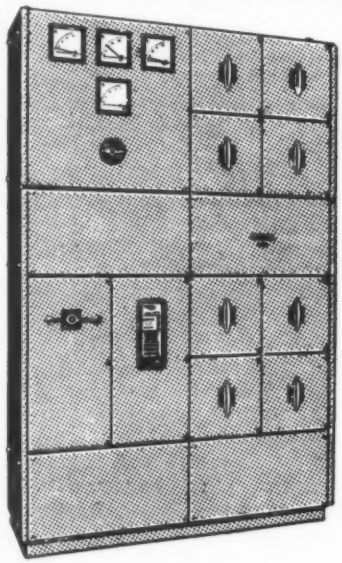
SE-10

LK
SWITCHGEAR



LK Unit-type, Iron-clad
Low-tension Switchboard
Assembled in India.



LK Sheet-Steel, Cubicle-type
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Switchboard.

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COPENHAGEN, DENMARK

Low-tension Switchboards designed for tropical service.

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Heavy Duty, Industrial Type
100—1,500 A Oil Circuit Breakers
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SWT/G1/59

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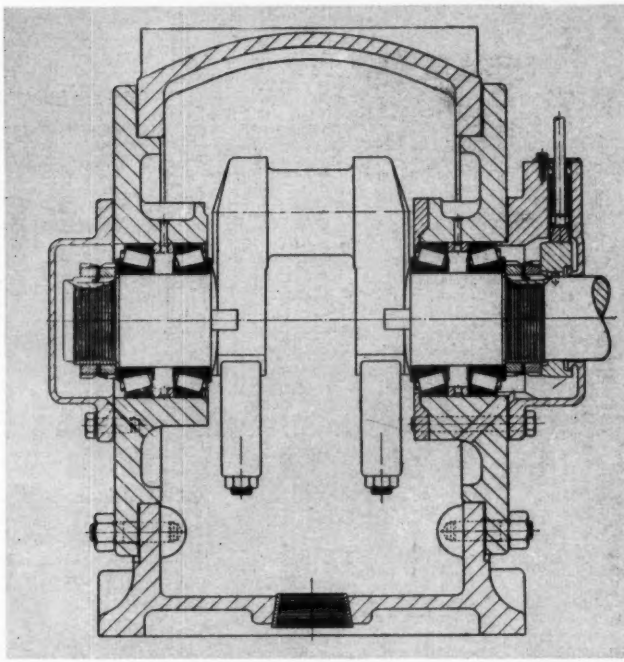
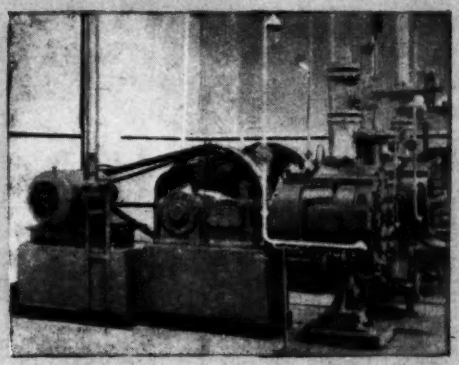


HOW WORTHINGTON LE BOURGET mounts the crankshaft of its HBV type vacuum pump on Timken made-in-U.S.A. tapered roller bearings.

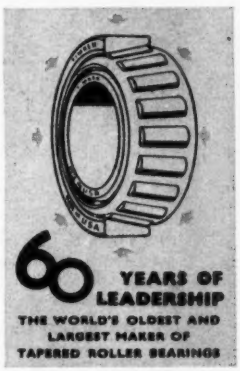


Worthington pump eliminates Crankshaft wear by using Timken Bearings.

Worthington Le Bourget mounts the crankshaft of its HBV type vacuum pump on Timken made-in U.S.A. tapered roller bearings. This eliminates crankshaft wear, keeps the pump working dependably day-in-and-day-out.

Like other internationally-known manufacturers, Worthington depends on Timken bearings because: 1) *They maintain positive alignment.* Timken bearings hold shafts concentric with their housings. They're tapered to take both radial and thrust loads (shown at right). 2) *They practically eliminate friction.* They're designed and precision manufactured to roll true; keep parts working smoothly with minimum wear.

To get the most for your bearing money, specify Timken made-in-U.S.A. tapered roller bearings. Made by the world's oldest (60 years) and largest manufacturer of tapered roller bearings. *Available world-wide.* The Timken Roller Bearing Company, Canton, Ohio, U.S.A.
Cable: "TIMROSCO"



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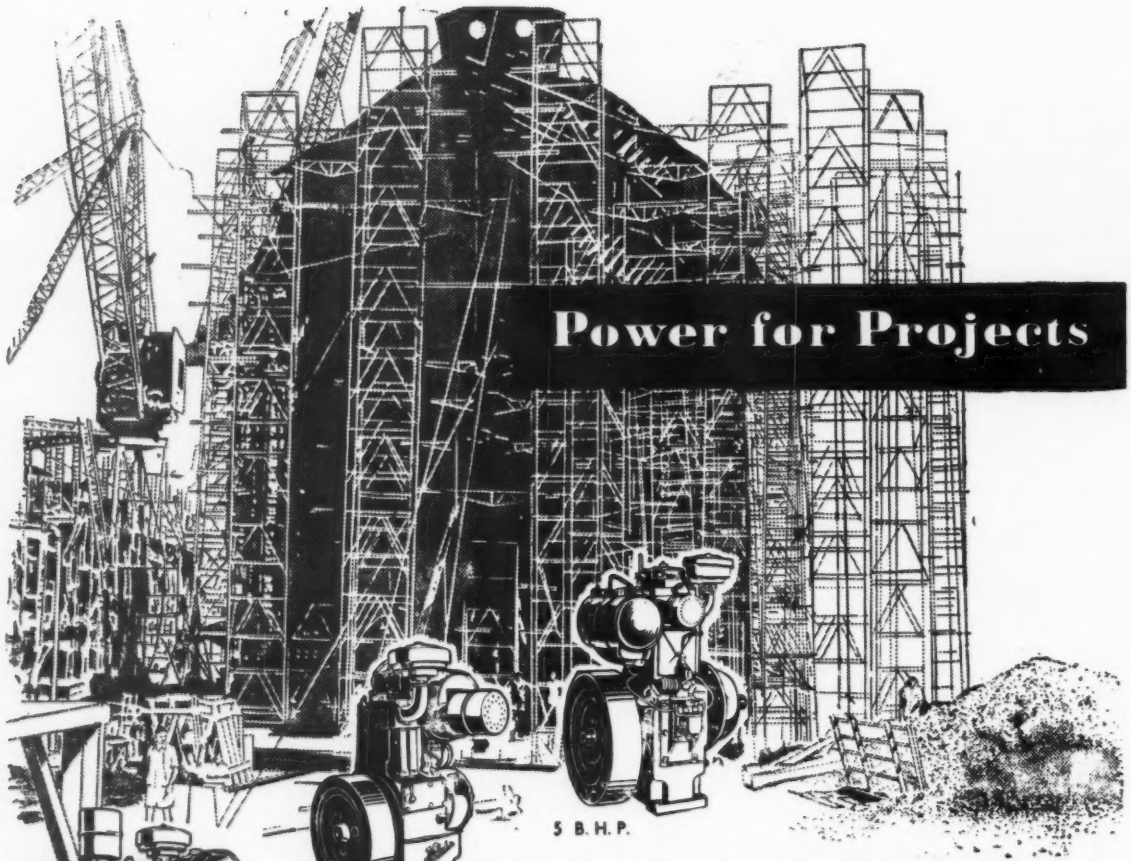

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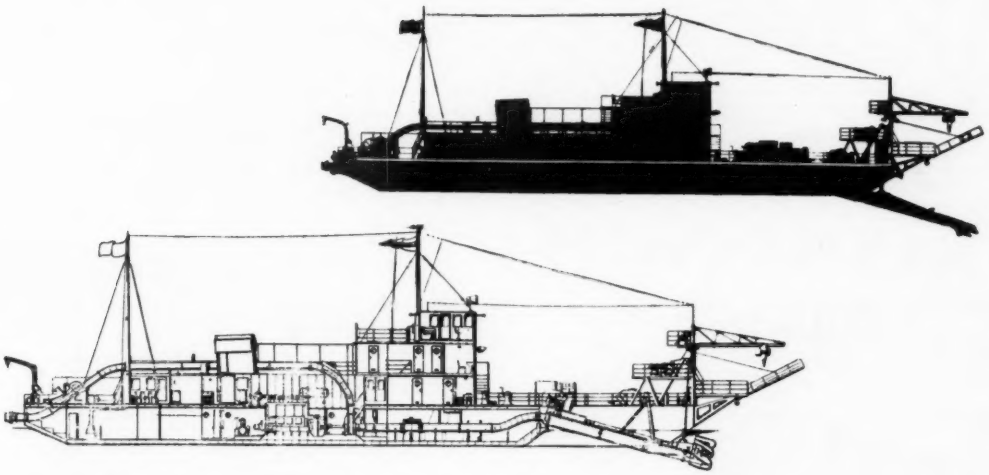

SUCTION DREDGERS OF CZECHOSLOVAK PRODUCTION

Since World War II the Czechoslovak Shipyards in Prague have delivered dozens of suction dredgers with capacities of 250 to 350 cubic meters/hours to other countries. The suction pump is driven by 4 S350 Skoda Diesel engine 380 HP. The equipment serves for dredging of rivers, canals, lakes and water constructions, to a depth of 11 meters. The dredger is controlled centrally from the dredger operator's table.

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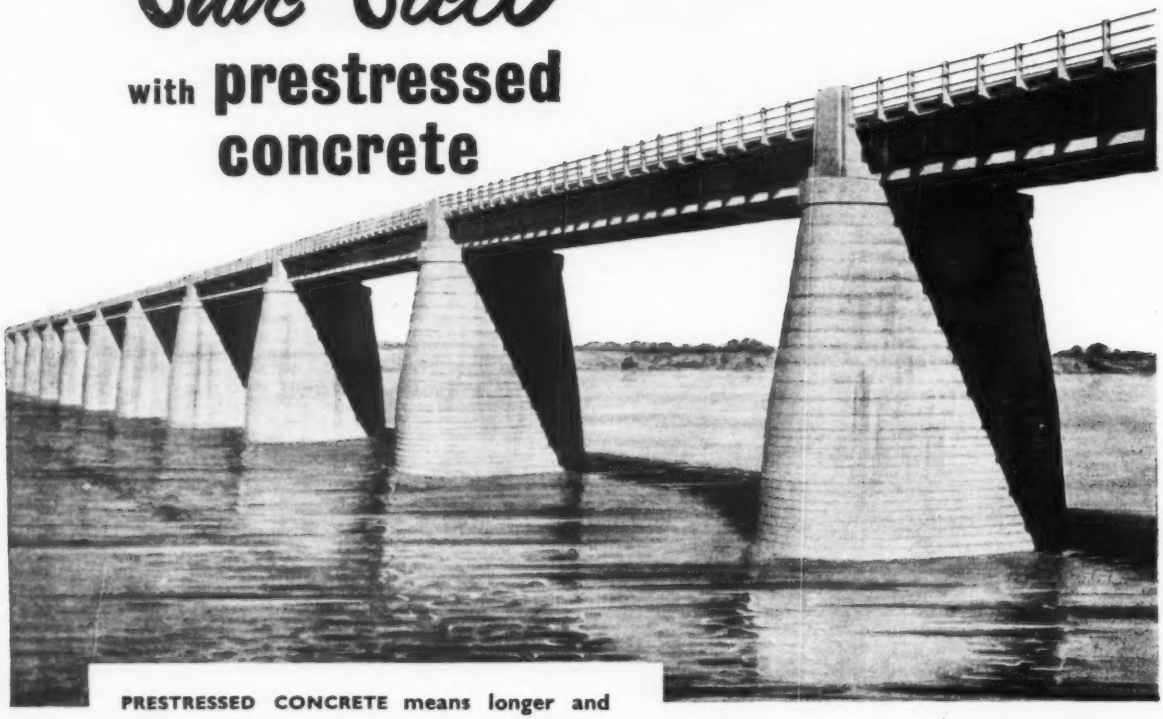
Save Steel with prestressed concrete



Mahi Bridge near Sevalia

PRESTRESSED CONCRETE means longer and lighter spans for more durable and economic bridges. Completed in 1955 at a cost of Rs. 16,00,000 the Mahi Bridge is an outstanding example among Prestressed Concrete Bridges in India numbering over 60 today.

Built with the Freyssinet system of Prestressing, the bridge has 19 spans of 125 feet each and prestressing has made possible the reduction of dead load in the structure. Amongst the many outstanding benefits of prestressing which result in overall economy, is the saving in the steel required.

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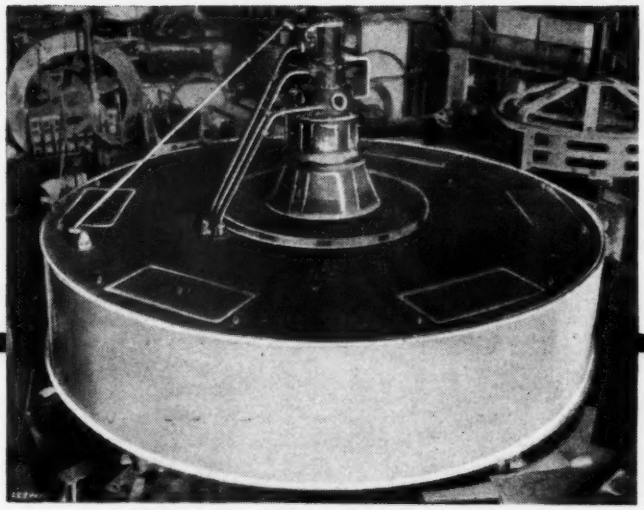

HITACHI

serves the national projects

One of the leading manufacturers of heavy electrical equipment, Hitachi Ltd., Tokyo, Japan, have helped to supply top quality machinery to many projects and power houses in India. Two photographs show a Hitachi 12000 h.p. Kaplan Type water turbine and a 10,000 kVA umbrella type generator, two units each of which have been supplied to Tungabhadra, one of the major hydel projects in South India.

Hitachi, Ltd.

Sole Agents in India

William Jacks & Co. Ltd.

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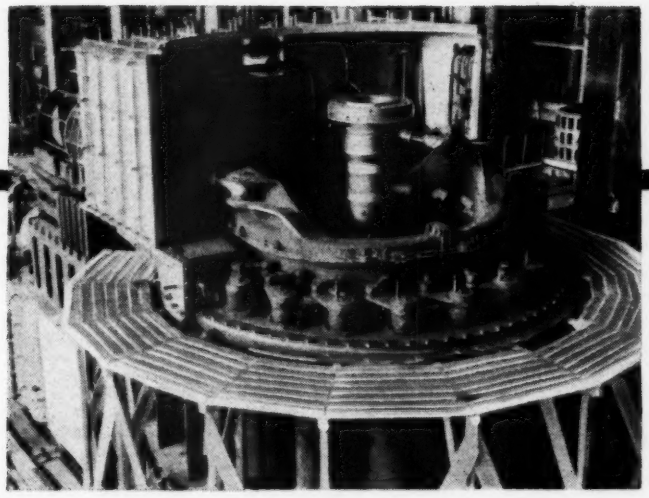

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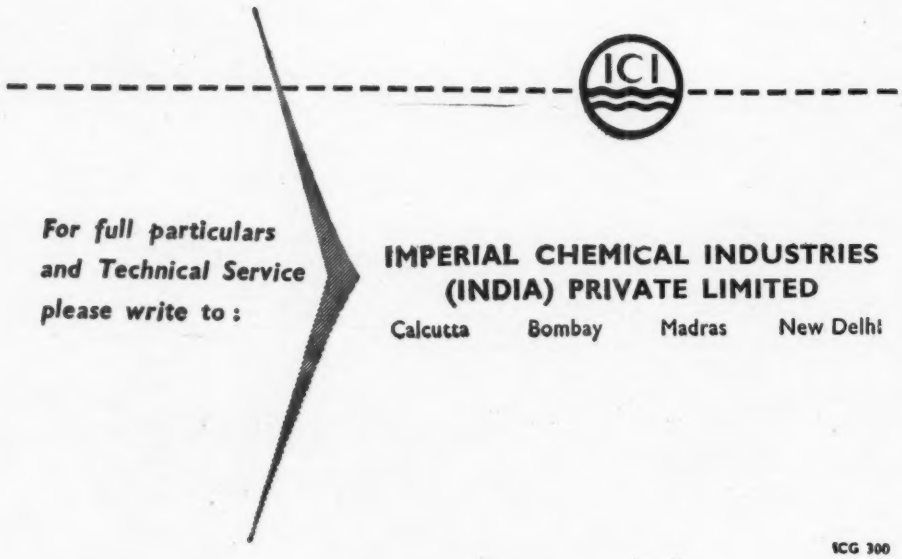
for
ALL PURPOSES



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From the Foden range of dumpers you will find one that exactly fits your needs, but whichever you choose, it will be as tough and dependable a vehicle as you could find anywhere in the world.

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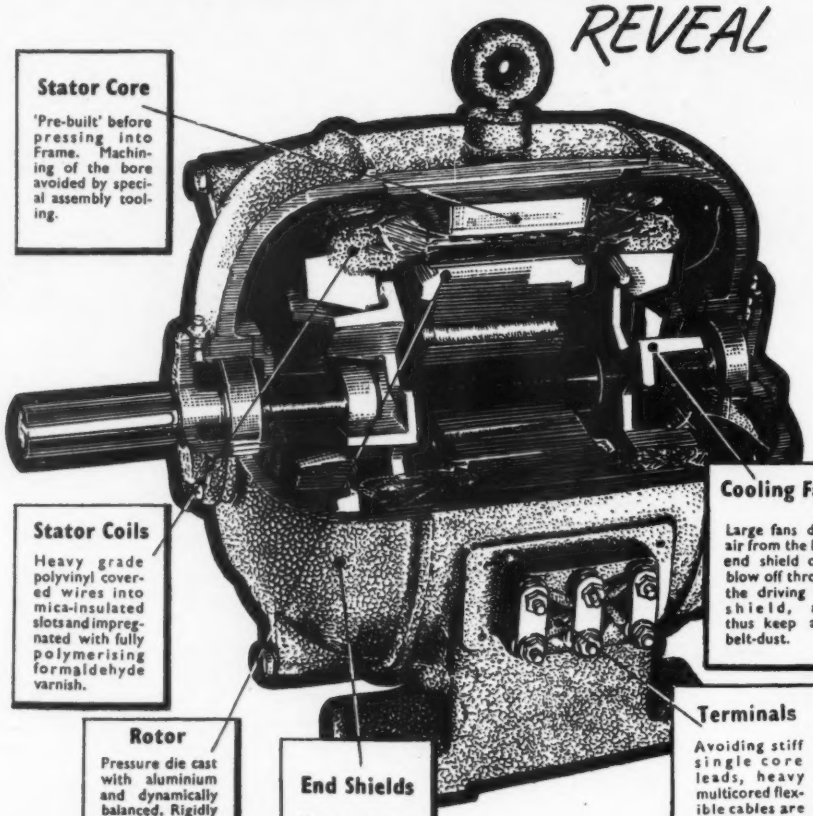
INSIDE FACTS

REVEAL



Stator Core

'Pre-built' before pressing into Frame. Machining of the bore avoided by special assembly tooling.

Stator Coils

Heavy grade polyvinyl covered wires into mica-insulated slots and impregnated with fully polymerising formaldehyde varnish.

Rotor

Pressure die cast with aluminium and dynamically balanced. Rigidly supported on over-sized ball bearings with ample grease capacity.

End Shields

Ventilating windows below the horizontal axis make the motor drip-proof.

Cooling Fans

Large fans draw air from the back end shield only, blow off through the driving end shield, and thus keep away belt-dust.

Terminals

Avoiding stiff single core leads, heavy multicored flexible cables are used to make working easier and less brittle.

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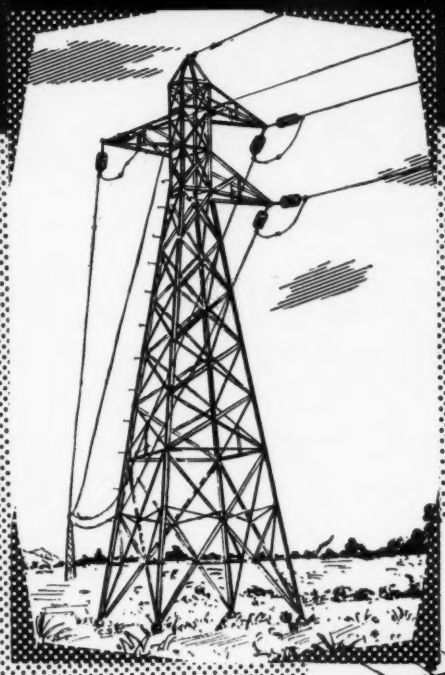
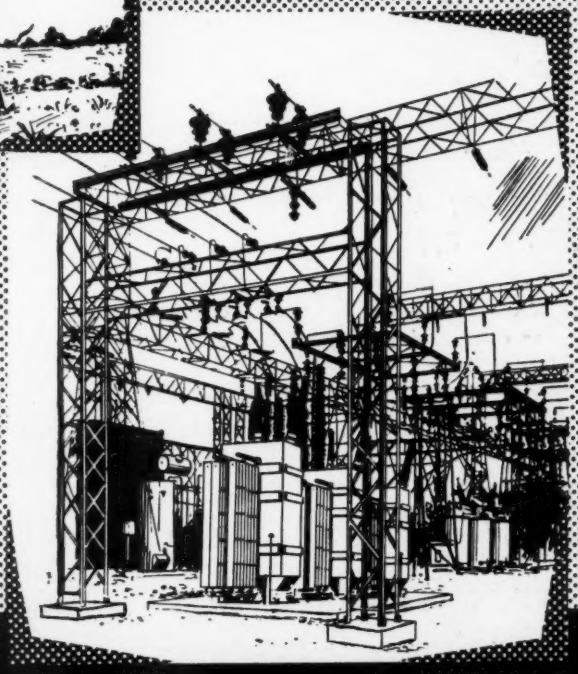


You will see CROMPTONS' Towers and Substation structures dotting the landscape. . . . . and especially here in our own country, where power is the life blood of practically all activities. For, these are the towering steel signposts of progress and achievement.



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Run the Firestone Guide Grip on any type of tractor—run it on the toughest farm and estate service, and you will find it gives twice the service of ordinary front tractor tyres. You get double the tyre life, yet the New Firestone Guide Grip costs no more than an ordinary front tractor tyre.

• LONGEST WEARING FRONT TRACTOR TYRE EVER BUILT
The new Dual Rib design gives 60% longer uniform wear on any type of tractor on paved roads and in the fields.

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The new design gives shorter turning and better cleaning in all types of soil conditions.

• BUILT-IN MUDGUARD OR DEFLECTOR STRIP
Protects side walls and beads from coarse stubble, sand and mud.

NO OTHER FRONT TRACTOR TYRE GIVES THESE ADVANTAGES

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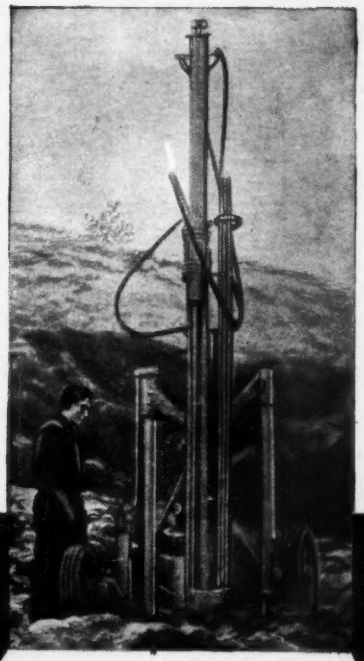
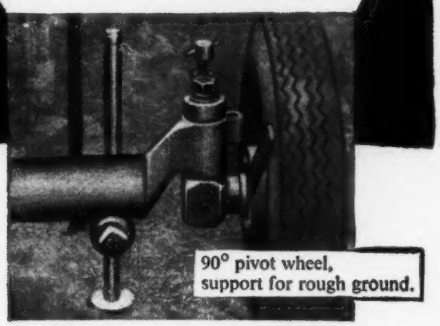


Atlas Copco Wagon Drills for precision benching



90° pivot wheel, support for rough ground.

Modern benching technique makes it possible today to blast with precision using a minimum of explosives. This calls for precision drilling, for which the right equipment is Atlas Copco one-man BVB 21 wagon drills. They can drill at any angle—vertical or very low horizontal. Front wheels can pivot 90° for working close to the bench or moving the drill sideways across the face. Powerful brakes and footings for uneven ground assure correct angles.

100% LARGER FLUSHING HOLES

The Sandvik Coromant 1¼" extension steels used with the BVB 21 are made of cold rolled steel, permitting a 100% larger flushing hole. This means approximately 100% better flushing. Extra flushing is possible, when dry drilling, through the water flushing hole.

DRILLS TO 75 FEET FOR BLASTING... ANY DEPTH FOR GROUTING

The chain feed of the 4" piston BBC 43 RBL rock drill is uniformly and forcefully driven by an air motor. Holes are bored out in diameters from 1⅞" to 3½" to a blasting depth of 75'. For exploration drilling it will go to any practical depth.

A cage holds drill steels upright and within easy reach. Exhaust noise is muffled with a silencer or, more often, led off by a 16' rubber tube—an Atlas Copco exclusive. For smaller operations, the Atlas Copco range includes smaller models such as the BVB 13.

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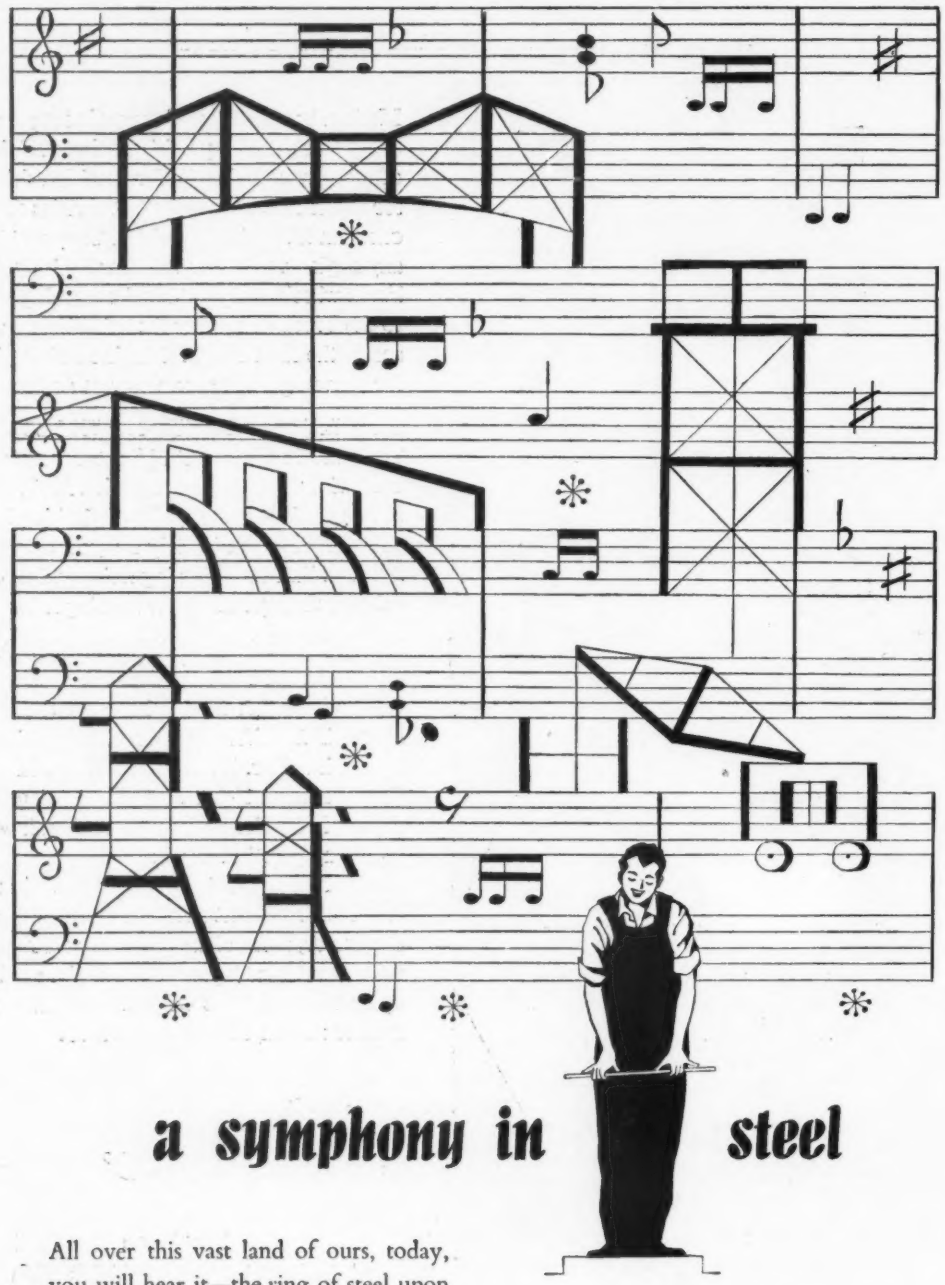

a symphony in steel

All over this vast land of ours, today, you will hear it—the ring of steel upon steel as a mighty nation surges ahead in its quest for industrial prosperity. It is a symphony of stupendous magnitude and Texmaco plays an important part in it. Here at Belgharia, work the Texmaco men and machines, manufacturing steel bridges for spanning the mighty rivers, steel transmission towers for carrying electric power; steel cranes for moving materials, speeding production; steel equipment for hydro-electric and irrigation projects— men and machines working in unison, playing the symphony in steel.

TEXMACO *serves India's basic industries*

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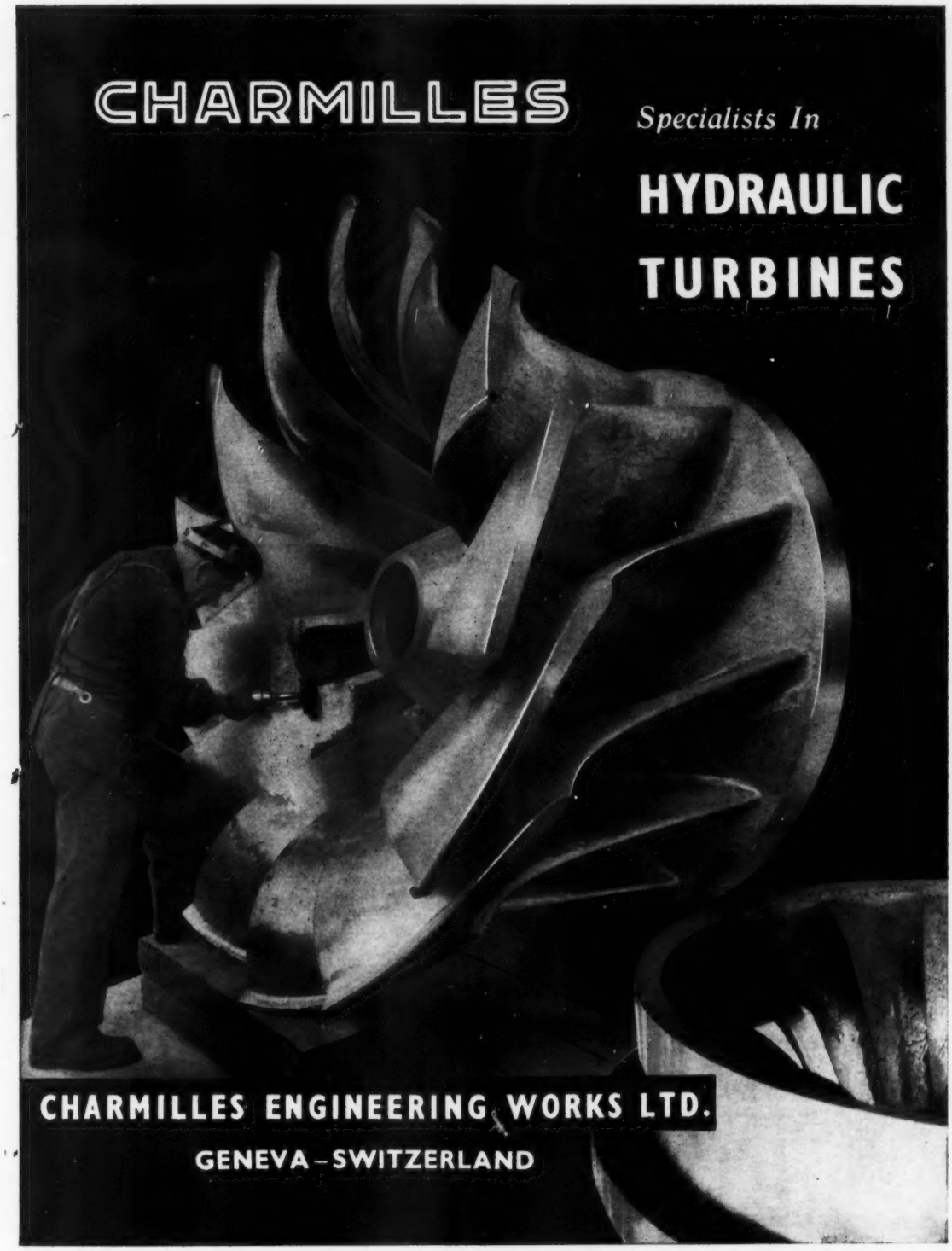

Runner of one of the **TUNGABHADRA** turbines

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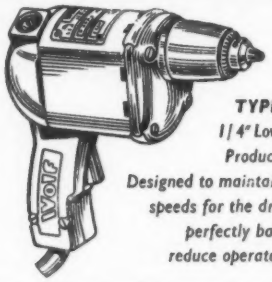
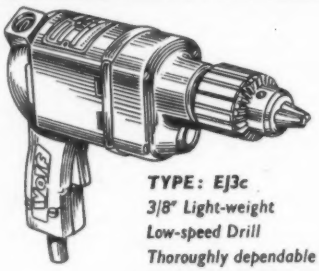
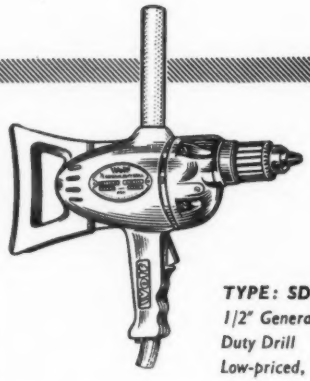


TYPE: EG2c
1/4" Low-Weight Production Drill
Designed to maintain correct speeds for the drill bits—perfectly balanced to reduce operator fatigue

A FINE PRODUCTION TEAM



TYPE: EJ3c
3/8" Light-weight Low-speed Drill
Thoroughly dependable tool combining immense power and stamina with extra lightness and portability



TYPE: SD4c
1/2" General Duty Drill
Low-priced, rugged, versatile

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Portable Electric Drills

Worldwide reputation for performance, efficiency, reliability

NOW MADE IN INDIA

"Wolf the work"

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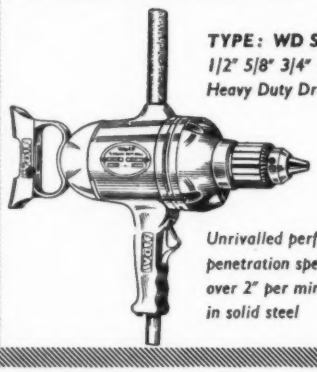

TYPE: WD Series
1/2" 5/8" 3/4" SUPER Heavy Duty Drills

Unrivalled performance—penetration speeds of over 2" per minute in solid steel

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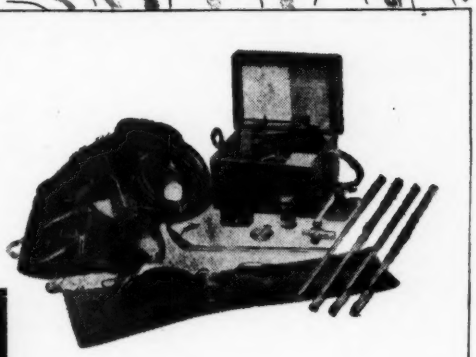
The most accurate hydraulic current meter ever developed



622—H
EXPLORATION OUTFIT

Gurley current meters have been in use all over the world for more than 70 years for measuring the rate of flow of water in shallow streams, irrigation ditches, canals, sewers, deep rivers of tidal waters. The 622-H Exploration outfit consisting of Basic Meter with spare parts and accessories, is an invaluable asset in geological surveys.

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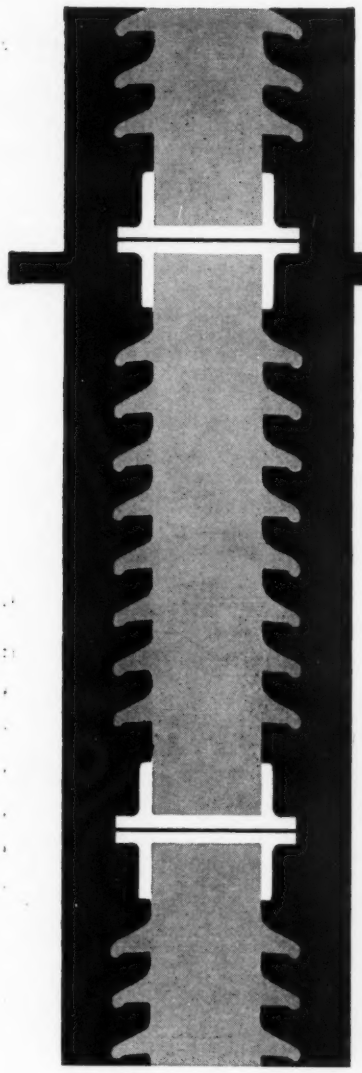

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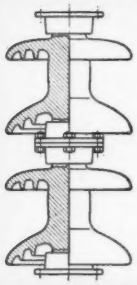

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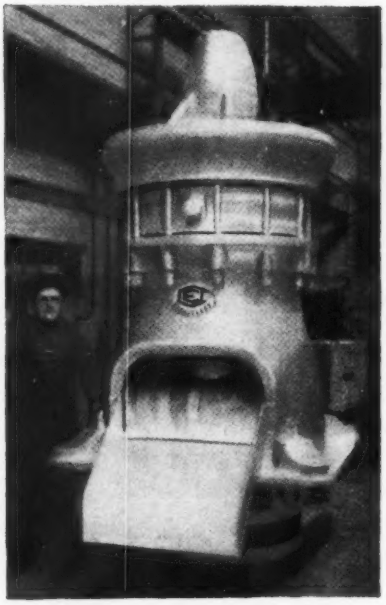

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Editor : K. K. Sinha — P. K. Menon : Mg. Editor

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TUNGABHADRA PROJECT NUMBER

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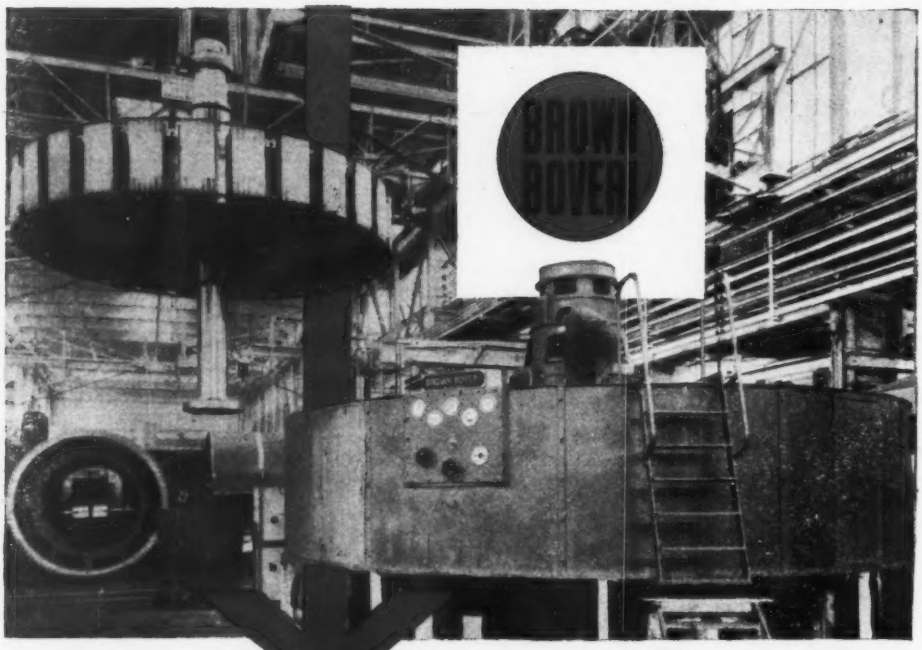

BROWN BOVERI WATERWHEEL GENERATORS

A view of the assembly, at the Works of Brown Boveri & Co., Ltd., Baden (Switzerland), of one of the four generators supplied to the Tungabhadra Dam and Hampi Power Stations. The generators were commissioned during the first half of 1957 and 1958. Output: 10600 kVA; Voltage: 11000 V; Speed: 214 r.p.m.

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2 x 54	,,	428	,,	(Switzerland)
2 x 53.3	,,	500	,,	(Switzerland)
2 x 54.1	,,	450	,,	(Columbia)
1 x 60	,,	600	,,	(Italy)
2 x 39	,,	83.3	,,	(France)
2 x 22.4	,,	720	,,	(Peru)
3 x 27	,,	600	,,	Machkund Project (Andhra State)
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Introduction

The Tungabhadra Project is one of the major river valley projects in India. It will have a tremendous, almost revolutionary, impact in the region commanded by it. Now that the Dam is completed (in 1953), and the headworks, the Low Level Canal on the right side and the first stage of electrification at the Dam and at Hampi are over, its beneficial fruits are becoming available to the country. The High Level Canal and the second stage of electrification await sanction.

Conceived as early as in 1861, the Project took almost a century to bear fruition. But such beneficial schemes are never too late. While the country reaps its benefits, it should not fail to remember the men behind the project, specially, Sir Arthur Cotton, Mr. Ireland, Mr. N. Parameswaran Pillai and Mr. M. S. Thirumale Iyengar.

The Tungabhadra Dam, one of the longest of its kind in the country, has attracted world-wide notice in the manner of its execution, and has contributed towards creating a sense of self-confidence and reputation in the technical ability of Indian engineers.

The Tungabhadra Project is also unique in the sense that it is courageously meeting the problem of transforming a whole system of agriculture in the region due to the inevitable impact of irrigation. Nowhere has this changeover been so difficult and complex as in this project area, and the authorities, in close co-operation with the Agricultural Department, are grappling with the problem bravely and, in the process, are evolving principles and policies which need careful study and adaptation in other areas. This experience should teach us the lesson, so far neglected, that irrigation policies and planning should be closely integrated with the agricultural needs of a given region and the two should be planned at the same time well ahead.

Another important historical lesson to be learnt from this Project is how not to establish a River Valley Authority. It has taken decades to decide on the Project and it has taken long years and multiplicity of authority to execute the project itself. Meanwhile political boundaries have been shifting, making decision-making still more difficult. One of the "benefits" of the Project that can, therefore, be shared by the whole country would be to establish River Valley Authorities in future in such a way that a unified leadership in the region and the Project is assured.

Finally, as Chairman Gokhale rightly points out, the Tungabhadra Project along with other major ones in the country having given us the initial self-confidence and prestige, it might now be necessary to measure the pros and cons of such mighty projects with those of the medium and small ones, at least for the time being, in a more detached manner and with the rich experience that we now possess.

But this in no way detracts the grandeur and the tremendous effort symbolised in the Tungabhadra Project. The following contributions will amply show how mighty was the work and the efforts behind it.

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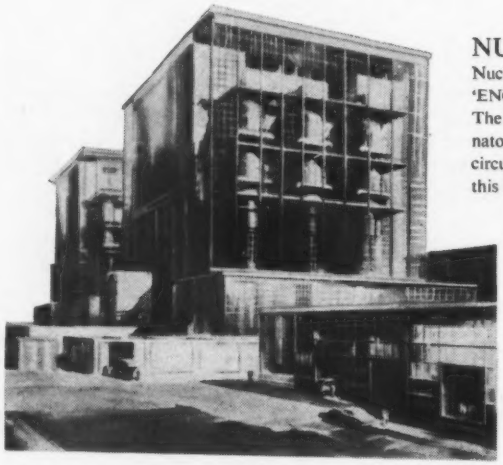
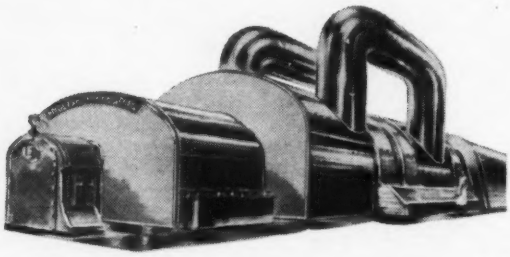


NUCLEAR. The first 500 MW Atomic Power Station (the world's largest Nuclear station) is under construction at Hinkley Point, U. K., by the 'ENGLISH ELECTRIC'—Babcock & Wilcox—Taylor Woodrow Consortium. The English Electric Company is supplying six main 93.5 MW Turbo-Alternator Sets, three 33 MW Variable Speed Turbo-Alternator Sets and a fifteen-circuit 275 kV duplicate Busbar Switching Station. The Reactors to be used at this Power Station will be of 'ENGLISH ELECTRIC' design.



STEAM. One of five 200 MW Steam Turbo-Alternators which the Company is supplying for the High Marnham Power Station, U. K. Early this year the Company received an order for two 275 MW Steam Turbo-Alternators for the New Blyth Power Station, U. K., and the sets are the two largest in-line turbo-alternators of their kind (50 cycles) in the world.

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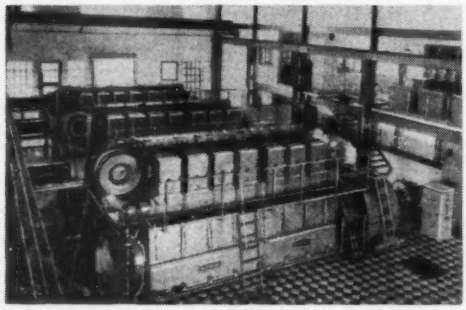

DIESEL. Three 'English Electric' Diesel Alternator Sets installed at Saateni Power Station, Zanzibar. The total output of the engines is 3,936 B.H.P. at 375 r.p.m. and the Station supplies the Island with a large part of its electricity.

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The Tungabhadra Project

by B. K. GOKHALE, I.C.S. (RTD.)
Chairman, Tungabhadra Control Board

THE end of the year and the beginning of a new year is usually a time for introspection, stock taking and the formulation of new resolutions for the coming year. An interval of one year is big enough in the life of an individual to review one's objectives, see how far they have been achieved and decide what further objectives it is worth while placing before oneself for attainment during the next year. But a period of one year is far too short in the life of an entity like the Tungabhadra which has had a chequered history since the time of the Ramayana when we first hear of it under the name "Pampa".

The tragedy of lands crying for water close to a river carrying vast quantities of water uselessly to the sea must have been the cause of deep anguish to rulers and administrators, who had the interests of their people at heart. As many as 9 anicuts were constructed across the Tungabhadra during the time of the Raya kings of Vijayanagar which irrigated several thousand acres of land on both sides of the river, chiefly by way of inundation. Human ingenuity and resources were then comparatively undeveloped and the construction of huge big dams like the Bhakra, Hirakud and Tungabhadra had not yet become feasible.

The need for a project to protect the districts of Rayalaseema against recurring famines was keenly felt in the middle of the last century when the Tungabhadra Project was conceived by that irrigation wizard of South India, Sir Arthur Cotton in 1861. But it took years of patient effort and negotiations to convince the authorities on both banks about the urgency and utility of the project and it was only 84 years later that the first milestone was reached in 1945 with two foundation stones laid on either bank by the then Governor of Madras and the Prince of Berar in Hyderabad.

The construction of the unitary dam was entrusted to two different agencies under the Public Works Departments of Madras and Hyderabad. It took a long time to settle even minor differences. The question of use of surkhi mortar vs. cement was settled only when that veteran engineer, Sir M. Visveswaraya, gave his award in favour of surkhi mortar for the bulk of the dam and cement mortar for spillways and certain other specified sections. Then came the police action in Hyderabad which virtually brought work on the dam to a standstill for some time. Followed various difficulties connected with the reorganisation of State boundaries. It is only now that the second milestone of the project may be said to have been reached with the final completion of the headworks, the Low Level Canal on the right side of the river and the first stage of electrification at the dam and Hampi Power House. The Low Level Canal of 217 miles has been completed and is irrigating some 40,000 acres in Mysore, and 35,000 acres in Andhra Pradesh. The first stage of electrification on the right bank has been completed with installed capacity of 36,000 k.W. at the Dam Power House and the Hampi Power House situated 15 miles below the headworks. The electricity produced is already being fully utilised. But irrigation is still in process of development and what is more important the second stage of electrification, 36,000 k.W., and the High Level Canal for irrigating the major portion of Rayalaseema still await sanction and provision of funds. The long suffering of people of Rayalaseema are still waiting for benefits of which hopes were held out to them nearly a hundred years ago.

On the left bank, about 65 miles of the canal have been completed out of a total of 127 miles. The rest of the canal is being constructed and it is proposed to make it navigable from the 24th mile to the 127th mile, in view of inadequate facilities for transport in this area. The work on the Dam Power House on the left bank is in hand. The total power potential on the left bank is of the order 1,04,500 k.W. But it is idle to guess when this potential will become an actual reality.

It has taken 13 years from 1945 to 1958 to reach what I might call the second milestone of this project. It may well take another 13 years till 1971 before the entire project is completed in all respects and the water stored in the reservoir is wholly put to beneficient use for irrigation and the generation of electricity so badly needed in this area. How long these benefits will be actually enjoyed by the people after 1971 is anybody's guess.

No wonder, that a feeling has grown in responsible circles that the next Five Year Plan should concentrate on medium and small projects capable of yielding quick benefits rather than huge projects which take years for completion and of which the benefits are long delayed. Time is running fast. The people are getting impatient. Democracy is on its

trial. We must produce quick results if democracy is not to fail in what is rightly considered the greatest hope of democracy in Asia.

India is famous for her small irrigation works dotted all over the country-side which were constructed centuries ago by local labour and are still performing a very useful function inspite of the ravages of time, the rise and fall of dynasties and continued neglect due to the disruption of village communities and lack of interest on the part of rulers. The construction, maintenance and repairs of these projects can be done by local agencies without reference to higher authorities and consequent interminable delays caused by such references. The benefits are direct and immediate. It is possible to enthuse the local people to take interest in the work and to do it on their own, even without wages. Damage caused by heavy rain or cloud bursts etc. can be easily repaired at least in one season. The various anicuts on the Tungabhadra and reservoirs like the one at Kamalapuram are examples of such works.

The main troubles with earthen dams have been difficulties of consolidation and the liability to give way before a sudden onrush of water. The first difficulty can now be got over by earth compacting machinery, sheep foot rollers and so on. The second difficulty can also be tackled by providing adequate cement concrete spillways and escapes which will enable floods to pass over without causing any great damage. Governments will of course have to help with technical advice, loan of compacting machinery for short periods and the construction of cement concrete spillways. There should be no difficulty in building up a series of small dams and reservoirs on every rivulet, with the help of local initiative and *shramdhan* for the benefit of the local people. The maintenance and repairs of such dams could easily be managed by local panchayats without any help from the Central or State Governments. I feel that a series of such dams will help in soil conservation, growth of trees and general improvement of health and morale of the people. Given adequate escapes and spillways, there is no reason why the earthen dams should not be much bigger and better than ever before. Earthen dams of 60 to 100 feet in height should prove ideal for the type of terrain in South India. Anything bigger will, of course, have to be treated as a major project.

Unfortunately, we in India are inclined to be very emotional and apt to sway from one extreme to the other. A good deal of research is necessary to determine the economics of big projects-vs-medium and small ones. The relative advantages have to be determined as regards the ratio of submersion to new cultivation, evaporation losses, soil erosion, resultant effects on the water table and so on. The costs of land acquisition, rehabilitation, lining of canals etc. have to be taken into account. None of these should normally be required in the case of medium and small projects. And, last but not the least, research must also take into account the cost of subsequent supervision and maintenance and the possibility of big works and canals going out of action because of neglect, sabotage or the exigencies of the political situation.

Inspite of spectacular advance made by science in the last few years, there is yet no substitute for water for irrigation. With our limited water resources and growing population, we must utilise every drop of water from the source of each river to its mouth for growing more food, utilising every possible bit of land for cultivation regardless of levels and commanded areas. Railways and roads have provided effective and efficient substitutes for navigation. Electricity can be generated from coal and other fuels. Atomic energy may soon replace water power for generation of electricity. It is only irrigation for which there is no substitute.

Now that our national pride has been satisfied to some extent by the construction of big projects like the Bhakra, Hirakud and Tungabhadra, it is just as well that we should turn our attention to medium and small projects, for the production of food in the shortest possible time. A few big projects will of course continue to be necessary. No amount of local initiative and effort will be able to provide an adequate substitute for the Rajasthan Canal taking off from the Harike barrage on the Sutlej. Rivers running in deep cuttings will necessarily have to be tackled in a big way to provide water for the neighbouring countryside. But an objective evaluation of the benefits is essential in all cases before a decision is taken in favour of big-vs-small projects. It may be hoped that the various Central and State agencies like the Central Water and Power Commission, the Central Board of Irrigation and Power and Institutes of Engineers will quickly undertake the necessary studies and give their objective evaluation of the pros and cons of the various issues involved in order to enable Governments to come to quick decisions and utilise the amounts available for irrigation and power development during the 3rd and subsequent Five-Year Plans to maximum advantage. The great shortage of foreign exchange and steel are too well known. Small and medium irrigation projects should help to conserve foreign exchange and produce quickly all the extra food needed for our ever-growing population.

Inspite of our vaunted civilisation, the threats to security and orderly progress are now more pronounced than ever before in the history of the world. Big projects offer an easy target for enemy aircraft. An increasing number of power houses are now being constructed underground or in cuttings under rock to protect them from aerial bombardment. Even this protection will probably be of no avail against nuclear weapons, organised sabotage and wanton destruction. Events occurring in different parts of the

(Continued on page 11)

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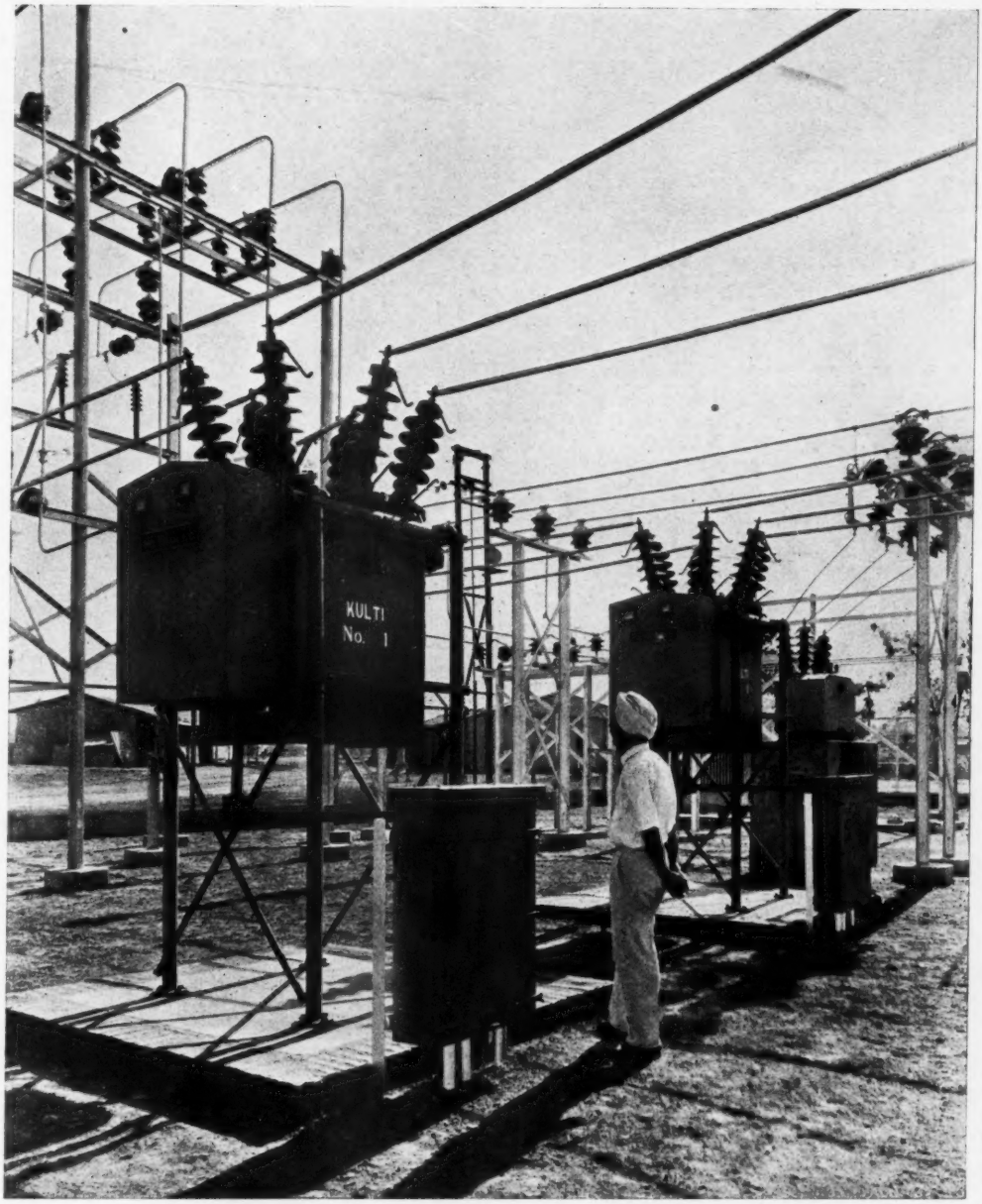

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Tungabhadra Hydro-Electric Scheme

by Late B. R. SOMAYAJULU,
M.I.E.E., M.I. Mech.E., M.I.E., (Ind.),
(Former Chief Engineer for Electricity, Andhra State)

THE Tungabhadra Hydro-Electric Scheme is one of the major multi-purpose projects undertaken in the composite Madras State in the post-war period under the First Five Year Plan. With the formation of Andhra State, and the consequent transfer of the seven taluks of Bellary District to Mysore State, this project has become a joint venture of governments of Andhra Pradesh and Mysore, the capital cost on the project and the power benefits being shared in the ratio of 80:20 respectively. The execution of the project is under the control of the Tungabhadra Board.

The Project comprises: (*a*) A power station at the foot of the Tungabhadra Dam called the Dam Power House, with two 9000 kW units and provision for two more units in the future; (*b*) a second power station called the Hampi Power House after the famous Hampi ruins at about the 14th mile of the irrigation canal, with two 9000 kW. units initially, with provision for one more unit shortly thereafter and a further unit (4th unit) later on, depending upon load development, and availability of additional water from the reservoir; and (*c*) a power transmission grid connecting the power houses with the consuming centres in the Bellary, Anantapur, Kurnool and Cuddapah districts.

CIVIL ENGINEERING WORKS

The Tungabhadra Project is primarily intended for providing irrigation facilities. Water for irrigation is drawn through a canal on each flank of the dam. The canal on the right flank called 'The Power Canal' is designed to carry a maximum discharge of 2500 cusecs, with occasional overload upto 200 cusecs extra. The eventual permissible discharge, governed by irrigation interests, is 2500 cusecs for eight months from break of south-west monsoon (say June 15th to February 15th) and 600 cusecs for the four summer months (February 15th to June 15th). The 2500 cusecs flow in eight months is made up of 1800 cusecs for new irrigation in the project under the low level canal (which starts below the tailrace of Hampi Power House at the end of Power Canal) and 700 cusecs for contribution to Kistna irrigation from the reservoir, which discharge will be let back into the river through the Gundlakeri Regulator, below the tailrace of Hampi Power House. Development of new irrigation in the project on both sides of the river is however expected to be fully realised only after 8 to 10 years from the opening of the reservoir for irrigation flow (July 1953). Till the year 1961 or so, there will be greater storage in the reservoir at the close of the flood season permitting a minimum draw-off of 1600 to 1000 cusecs in the summer months, depending on the reservoir storage available. At about the 14th mile of the alignment of this canal, a drop in ground level of about 110 feet occurs and this head is also utilised for power generation.

Thus the water mainly intended for irrigation is made use of for generation of power at two different places prior to being utilised for irrigation.

DAM POWER STATION

Power Potential

The firm power available from the 1600 cusecs minimum discharge at the dam will be 12,500 kW. @ 60 p.c. L.F. The seasonal power, however, with 2800 cusecs maximum discharge, is 26,500 kW.

Hydro-Electric Pipes and Intakes

Four steel pipes of 11′0″ diameter and 1/2″ shell thickness have been installed in the dam with intakes and head gate controls. Only two of them are utilised initially, the other two having been blank flanged.

Supply of water to the turbine is further controlled by 11′0″ diameter electrically operated butterfly valves located outside the power station.

Turbines and Generating Machinery

The two vertical shaft, Kaplan turbines of maximum capacity 13,800 H.P., 214 R.P.M. each now installed were manufactured in Switzerland. These are coupled with two 9000 kW. 3 phase 50 cycles 11 kV. alternators, also manufactured in Switzerland. The indoor switchgear is also supplied by Swiss manufacturers.

Power House Building

The power house building is designed to accommodate all the four units, though only two units are installed initially.

The foundation of the machines and the stanchions supporting the superstructure, gantry and crane are taken down to hard rock. The power house superstructure is of R.C.C., on account of the shortage of steel, in keeping with the general appearance of the dam. The electrically operated overhead travelling crane for handling heavy lifts is of 75 ton capacity.

Transformer Yard

The transformer yard is located adjacent to the power house at right angles to its longer axis. To avoid extensive excavation for the yard, the equipments are arranged at different levels. The transformers are kept at the power house floor level and the other structures are kept at higher levels to suit the general ground formation as far as possible.

Two transformers of capacity 10.6 mVA each are installed to step-up the generated voltage from 11 kV to 66 kV for transmission to distant centres.

The line take-offs at the dam station are as follows:

66 kV single circuit lines to Bellary; (Constructed under the Ceded District Scheme).

66 kV double circuit lines to Hampi Power House;

66 kV single circuit line to Sokke;

66 kV single circuit line to Hyderabad (Future).

Two 1500 kVA 66/11 kV step-down transformers have been provided for giving 11 kV supply for local services and emergency stand-by auxiliary supply to Hampi Power House.

The outdoor switchgear such as circuit breakers, isolators etc., are from Switzerland. The breakers are of the minimum oil content type.

The 66 and 11 kV structures are of galvanised steel.

Station Auxiliaries

Power for station auxiliaries is supplied from two unit transformers of capacity 500 kVA 11kV/400 volts each connected to the alternator terminals.

A house set comprising of 375 kVA 3 phase 50 cycles 400 volts generator coupled to a 680 BHP Francis turbine is provided for alternative feed to the station auxiliaries in case of failure of supply from the main generating sets.

HAMPI POWER STATION

The Head works

When the Power Canal carries a discharge of 2600 cusecs the maximum seasonal power that could be developed will be about 31,800 kW at 60p.c. load factor at a net head of 110 feet at the Hampi Station. But in summer a minimum flow of about 1600 cusecs only will be available and the power that could be generated with this discharge will be about 19,500 kW at 60p.c. load factor. During the earlier stages of irrigation it may be possible to draw higher firm power by regulating the discharges from the reservoir more evenly.

The total firm power potential of dam and canal power houses is 32,000 kW and the total seasonal power potential at the two stations is 58,300 kW.

The forebay for Hampi station has a storage capacity of 28 m. cft. The purpose of the forebay is to store the canal discharge during non-peak hours and admit this during the peak load period. The forebay is located at the end of power canal and in the south-east corner of the famous Hampi ruins. In view of the historical importance of the ruins, the site for the forebay has been fixed in consultation with the Archeological Department of the Government of India so as to cause least damage to the monuments in the area.

The forebay has been formed by composite dam with earth backing and an earthen bund with clay puddle hearting and gravel casing. As rock is not available at reasonable depth for foundations in this area, a masonry dam could not be built. However, the portion of the bund where the pipe intakes are located is in masonry, founded on rock.

Low Pressure Pipe Lines

Out of the two low pressure steel pipe lines 18′0″ in diameter, each capable of discharging 2200 cusecs proposed for peak load conditions, only one pipe is installed initially. The intake structures for both the pipes together with the gates, hoists and trash racks are however being constructed even at this stage. The fabrication and erection of the second pipe have been taken up in hand.

Surge Tank

Each of the two low pressure pipe lines end in a different surge tank of steel. Only one surge tank is being constructed initially. The second low pressure pipe line including the second surge tank will be installed later.

Penstocks

Four steel penstocks, two from each surge tower will be provided ultimately, but only two have been installed during the initial stage. Grading for all the pipe lines is being done initially.

Each pipe will be 12′0″ in diameter capable of supplying a maximum discharge of 1100 cusecs for peak load requirements. Each of these penstocks will be connected independently to a turbine in the power house.

Each penstock will be provided with one set of butterfly valve, air valve at the surge tank and another set of butterfly valve, pressure recorder, and venturimeter at the power house end.

Power House Building

The power house is located in a cutting and is 200 feet long and 60 feet wide for accommodating the eventual installation of four generating units. Only two units have been installed initially. The power house sub-structure is of R.C.C. as in the case of dam power house.

Turbine and Generating Machinery

Two vertical shaft, Francis turbines each of maximum capacity 12,600 H.P., 214 R.P.M. of Swiss make have been erected. They have been coupled to two 3 phase 50 cycles 11 kV 9000 kW alternators, also manufactured in Switzerland. The indoor switchgear is also of Swiss origin.

Tailrace

The tail race level is fixed to suit the level of the low level canal which is fed by the tailrace.

Transformer Yard

The transformer yard is of outdoor type and is located at right angles to the power station. Excavation for the yard is in benching as at the dam power house. Two transformers of capacity 10.16 mVA similar to those at dam power house have been installed.

The following 66 kV line take-offs have been provided at Hampi Power Station:

1. 66 kV double circuit interconnectors to dam power station;
2. 66 kV feeder to Bellary with space provision for a second feeder to Bellary.

Station Auxiliaries

Power for station auxiliaries is being supplied from two unit transformers of capacity 500 kVA 11kV/400 volts each, connected to alternator terminals. There is an additional 500 kVA 11 kV/400 volts out-door station transformer fed by the 11 kV dam-Hampi feeder to provide alternative feed to the station auxiliaries in case of failure of supply from main generating sets.

TRANSMISSION SYSTEM

There are around 600 circuit miles of 66 kV main transmission lines and 116 circuit miles of 33 kV sub-transmission lines located in the Tungabhadra Scheme area, extending as far as Renigunta, where they meet the transmission lines under the Nellore Thermal Scheme. The Mysore transmission system comprises the 66 kV lines from dam to Sokke with sub-stations at Sokke, Kudligi, Tornagallu etc.

Sub-Stations

The Power from the Tungabhadra is stepped down to 33 and 11 kV for distribution purpose at the following main sub-stations in Andhra Pradesh, numbering 20 in all.

66 KV Sub-Stations		*33 KV Sub-Stations*
Bellary	Guntakal	Alur
Gooty	Dhone	Adoni
Kurnool	Tadipatri	Rayadrug
Erraguntla	Cuddapah	Emmiganur
Rajampet	Kodur	Nandyal
Anantapur	Penukonda	Banganapalle
Dharmavaram	Hindupur	

The installed transformer capacities are as follows:

Name of the sub-station	*Number and Capacity of transformers.*
Bellary ..	2 Nos. 1000 kVA and 2 Nos. 3000 kVA.
Guntakal ..	2 Nos. 1000 kVA.
Gooty ..	3 Nos. 3000 kVA and 1 No. 1500 kVA.
Dhone ..	3 Nos. 1500 kVA.
Kurnool ..	3 Nos. 3000 kVA.
Tadapatri ..	2 Nos. 1000 kVA.
Erraguntla ..	2 Nos. 1000 kVA.
Cuddapah ..	3 Nos. 1500 kVA.
Rajampet ..	2 Nos. 500 kVA.
Kodur ..	2 Nos. 500 kVA.
Anantapur ..	2 Nos. 1000 kVA.
Dharmavaram	3 Nos. 1000 kVA.
Penukonda	1 No. 500 kVA and 1 No. 250 kVA.
Hindupur ..	2 Nos. 1000 kVA.
Adoni ..	2 Nos. 1500 kVA.
Emmiganur ..	2 Nos. 500 kVA.
Rayadurg ..	2 Nos. 500 kVA.
Alur ..	2 Nos. 260 kVA.
Nandyal ..	2 Nos. 1000 kVA.
Banganapalle	2 Nos. 500 kVA.

There are two 3000 kVA. synchronous condensors, one at Gooty and one at Renigunta for voltage regulation and stabilisation of the Andhra Transmission System.

AGENCY OF EXECUTION

Prior to the formation of the Andhra State on October 1st, 1953 the entire scheme including the irrigation part of it was being executed by the Public Works Department and Electricity Department of the composite State of Madras. Similarly, works on the Hyderabad side were executed by the State Government of Hyderabad. Subsequent to the formation of the Andhra State and the consequent change due to a portion of the Bellary district, comprising of seven taluks where the dam and the two appurtenant works are situated, having been ceded to the Mysore State, the Tungabhadra Board was formed by the Government of India.

The present set up of the Board with effect from 15th March, 1955 consists of: (1) One Chairman appointed by the Government of India; (2) One

Member nominated by the Government of India; (3) Two Members from the States of Andhra Pradesh and Mysore, the concerned States.

The Board has the powers of the State Government and is in charge of all the common works connected with the scheme, including the regulation of water supplies for irrigation and power.

CAPITAL COSTS

The scheme as originally estimated is to cost about Rs. 7.3 crores initially rising to about Rs. 8 crores at the end of ten years. Consequent to the formation of the Board, the scheme estimates had to be split up into three parts corresponding to the Mysore, Andhra and Board portions. The estimates also have since been revised. The power developed as well as the capital expenditure or the Board portion of the scheme is to be shared in the ratio of 80 : 20 by Andhra and Mysore. The details of the break-up estimate figures are as follows: Common works under the Board: Rs. 700 lakhs; Andhra Transmission lines etc: 363.47 lakhs; and Mysore Transmission lines etc: 32 lakhs.

The common works comprise: (1) The two power stations at dam and Hampi; (2) 66 kV interconnecting lines between the two power stations; (3) 66 kV transmission lines from the two power stations to Bellary; (4) Bellary sub-station; (5) temporary dam sub-station (66/11 kV); and (6) 11 kV line from Dam to Hampi Camp.

PROGRESS OF WORK

The field work for the scheme was commenced in 1952. Civil works at dam power house are completed. The work on the two generating sets and connected accessories at the dam power house and at the Hampi power house have been completed and power supply commenced. Power to the extent of 36,000 kW. is being supplied to the districts of Bellary, Raichur and Chitaldurg in Mysore State and Kurnool, Anantapur, Cuddapah, Chittoor and Nellore in Andhra Pradesh.

(Continued from page 15)

FOUNDATION TREATMENT IN THE TUNGABHADRA DAM

and water, interconnections among 6 holes were detected. This hole took 67.2 cubic feet of cement. After grouting of this hole was completed test holes were drilled to find out the effectiveness of grouting. Cores taken out of these holes revealed cement particles below 10th feet from top. The average cost of grouting the hole drilled in foundation rock including cost of cement and the charges for shifting the equipment has been roughly Rs. 2/- per Rft.

High Pressure Grouting

This consists of a series of holes drilled 40 feet into rock located on a line 15'-9" in rear of the axis of dam. The holes are spaced at 40 feet centres. These are drilled from inside the drainage gallery after the dam has come upto about 100 feet above rock level. Drilling is done through pipes extending 3 feet into rock. Prior to the starting of masonry, holes are drilled 3 feet into rock at 40 feet centres and 3 inches metal pipes fixed in these vertically and care is taken to see that these are maintained vertically during the progress of masonry. These pipes extend upto the floor level of the gallery. The drilling of these holes was done by two C.P.55 diamond core drills operated by compressed air and supplied by Messrs. Consolidated Pneumatic Tool Company. Ltd. These were worked from under the gallery.

FOUNDATION DRAINAGE

This is achieved by providing a series of drainage holes 3" diameter, about 10 feet centres and drilled 35 feet into the foundation rock. The holes are located on a line parallel to and 3'-6" downstream from the grout curtain. Prior to the starting of masonry, holes of 1 foot depth are drilled into rock and drainage pipes 4 inches diameter are fixed vertically and taken upto the floor level of gallery. The top of these pipes is provided with a toe and a plug. Drilling is done through these pipes after the high pressure grouting within a radius of 200 feet has been completed. The seepage water that comes up through the drainage holes flows into the longitudinal drain of the drainage gallery through the transverse pipe from the drainage pipe and collects in one or two pumps, provided in the gallery from where it is pumped out.

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Salient Features of the Construction of Dams

by K. V. EKAMBARAM, I.S.E.
Chief Engineer, High-ways, Madras.

DIVERSION OF THE RIVER

PRACTICALLY, the first item of work in the field to be taken up for the construction of a dam, is the diversion of the river. This is generally done in two ways. The river is completely diverted outside the work, so that the work can go on throughout all the seasons. A typical case is that of the Bhakra Dam where the river Sutlej is diverted through two 50 feet diameter tunnels drilled through the two abutments on either side. Heavy cross bunds are put above and below the damsite and the work goes on unhampered all the year round. A slightly different case is that of Maithon Dam in the Damodar Valley, where the main earthen dam is in the river bed, the river being diverted for this purpose through a channel cut in the flank. The masonry portion of the dam is built across this channel. The other way which is suited to the case of a wide river is to allow it to run its own course, but in a constricted width. In the dry season, when the discharge is low, the river is transferred from place to place and the work is allowed to progress all along. It is also allowed to flow through the river sluices or construction sluices built in the dam. There has to be always a river section, which is lower than the flanks to take care of the river in the flood season. This was the method adopted in the Tungabhadra dam and had to be properly planned every year with reference to the river flows. In the beginning cofferdams were constructed isolating the two flanks and inside these, the foundation excavation was commenced. A low regulator across the river course with narrow spans was also constructed, with the object of transferring the dry weather flow wherever desired, by closing the requisite vents. In the subsequent dry seasons, the river bed could be easily tackled, by diverting the flow from one place to another, and by erecting suitable divide walls. In a later dry season, the water was allowed to flow through eight construction vents—5′×5′, with an archway over the same—the same size as the drainage gallery. Enough arrangements had to be made so that later on when they were blocked, there could be proper bonding with the old masonry. When the regular river sluices were formed, the dry weather flow was sent through these. The monsoon flow went over the partially completed spillway every season. In the Tungabhadra there was also the problem of diverting three old irrigation channels which ran across the dam site. This was done without any kind of interruption to irrigation.

EXCAVATION OF FOUNDATIONS

A dam has to be naturally founded on sound rock. Of course, thorough geological investigation and exploration of site by drill holes, pits, etc., should have been done before the site was chosen. The over-burden is easily removed by manual labour or by machines if they are easily available. There may be a certain amount of decomposed rock or loose rock, which can be removed by blasting only. For this purpose compressed air will be quite useful. This is necessary for drilling holes with speed in the rock. In the Tungabhadra Dam, stationary compressors on the right flank and portable compressors on the left flank were used. Then jack hammers, a drill sharpening plant etc. are necessary. The excavated materials have got to be removed as fast as they are excavated. A tramway plant with a few locos and tipping waggons is most probably the cheapest for this job. In a big job, of course, shovels or draglines and dumpers may be the appropriate machines.

After rough excavation to a good rock is over, the final removal of slabby and the drummy rock which has got loosened from the main rock due to blasting, is done by hammers, chisels and wedges. For this purpose every spot in the foundation is tapped sharp with a 16 pound hammer. All sharp edges in the foundation rock are chamfered so that there may be no undue stress intensity. Sloping surfaces are benched but this was found difficult in the epidiorite of the Tungabhadra Dam, as the epidiorite which came out in layers, was found to have the same slope after removal. In such places there was no other go, except to drill holes about 3′ deep and fix anchors of 1″ steel bars.

One cannot expect to have always smooth sailing in the matter of foundations. At the left flank of the Tungabhadra Dam there was a gully across the foundations. This was about 140′ wide at top and 40′ deep. The loose materials had to be exca-

vated but luckily good rock was got at the bottom. This involved a large amount of excavation and heavy dewatering to be carried out during the short period of a working season. There were a few other soft pockets where excavation had to be carried deep. There was a seam right across the foundations in another place. Deep holes were drilled in this and the seam was washed and grouted. Many other precautions were taken here to prevent seepage.

DRILLING AND GROUTING

The next important work in the foundations, is drilling and grouting. This is necessary to prevent leakage through any seasons in the foundations which could cause uplift. This is done in two stages. In the first stage, rows of shallow holes are drilled and grouted at a low pressure under the base of the dam. This is known as surface grouting or blanket grouting. Besides preventing seepage, this helps to consolidate the foundations. Usually the drill holes are in 2 or 3 rows parallel to the axis of the dam, the number of rows depending on the quality of foundation rock. They are 20′ deep and 20′ apart and holes in the different rows are staggered. The upstream row is located first 2′ downstream of the axis. If the rock appears to be poor, intermediate holes are put in. These holes are drilled with waggon drills. After this process of drilling comes grouting. Prior to grouting the holes are cleaned and washed. Cleaning is done by compressed air. For grouting short G.I. pipes $1\frac{1}{2}''$ in diameter are fixed in cement on the top of the holes and this is allowed to set for a few days. These pipes are necessary for connecting the water supply hose or the grout hose and have screw threads cut at their top ends for this purpose. Grout is pumped into these holes by a grout pump. The cement grouting is generally started with a ratio of 1 : 10 (1 of cement to 10 of water) and finally ends with a richer proportion of 1 : 4 to 1 : 5. The pressure maintained for shallow holes is generally from 40 lbs. to 70 lbs. per square inch.

The second stage in the matter of preventing seepage across the foundations consists of drilling a deep line of holes and grouting it under a high pressure. This grouting is done after the dam construction has proceeded considerably, so that due to high pressure used, the foundation rock is not disturbed. This deep curtain is under the drainage gallery and to facilitate drilling of holes from the gallery vertical pipes are set up from the foundations to the floor of the gallery as construction proceeds. In the Tungabhadra Dam, these holes were 40′ deep and at 40′ intervals. A baby size diamond drill was used in the gallery for drilling the holes. The pressure used for grouting ranged from 150 pounds to 200 pounds per square inch. In very high dams one or two more deep curtains may be introduced.

MASONRY

Dams for storage of water can be constructed with various kinds of materials, as concrete, stone, earth, rock, reinforced concrete, etc. But it is proposed to deal with construction with stone masonry only here, as it was this that was adopted for Tungabhadra Dam. This construction with stone is eminently suitable for employment of manual labour and the southern part of our country has enough of labour who are accustomed to work with stone. Besides, good granite is available there at almost every place.

The older dams in South India have been constructed with stone in lime-surkhi mortar only. In the non-spillway sections of the Tungabhadra Dam, the same mortar was adopted. But in the spillway section and round about the sluices, cement mortar was used. But 20p.c. of the cement was replaced by finely ground surkhi powder. This was done in the interests of economy and at the same time, it had the beneficial effects of improving the workability and keeping down the heat of hydration.

The proportion of lime-surkhi mortar used was 1 lime, 1 surkhi, 1 sand (1 : 1 : 1) by volume. It was found that 1 : 2 : 2 proportion was quite as good and this was adopted at higher levels. In the cement mortar sections, the front face to a thickness of 9′ was built using a richer proportion of cement mortar, namely, $1 : 2\frac{3}{4}$. The rest was built with cement mortar 1 : 4.

The stone used for the masonry shall be sound, clean, hard, durable and tough. It should be free from decays, sand holes, veins, flaws, cracks, and other defects and must have as far as possible uniform colour and texture. The stone shall not be flaky but shall be solid in appearance. The stone used in hearting shall generally weigh between 80 to 100 pounds so that a man or mason can conveniently handle it. This means the volume will be between $\frac{1}{2}$ to $\frac{3}{4}$ cft. It is preferable the front and rear face work are in courses and the stones for the same are specially prepared so that closer joints and a good watertight face can be got.

At the Tungabhadra Dam the stones for face work were 1′ thick at bottom layers and 9″ thick at higher levels. They were originarily 11″ wide and 18″ long as a minimum and were prepared for being built as headers and stretchers alternately. The faces were hammer dressed with bushes not projecting beyond $\frac{3}{4}''$ and in the case of stones used for front face had their sides, bed and top one line chisel dressed for 4″ from front face and the portion beyond tapered inwards slightly, so that thickness of joint may not exceed $\frac{1}{2}''$ in chisel dressed portion and $\frac{3}{4}''$ beyond. But in actual practice beyond the first 4″ the joint spacing was greater than $\frac{3}{4}''$ specified and it was well packed with spalls and mortar. In the case of rear face of spillway

section, the face stones were in addition one line chisel dressed on their faces. In the case of rear face of non-overflow section the stones were hammer dressed on all faces. The face stones were very heavy ranging in weight from about 250 lbs. to 560 lbs. or from $1\frac{1}{2}$ cft. to $3\frac{1}{2}$ cft. The heaviest stones were those used in the baffle-wall.

The lime is to be burnt from approved lime stone or kankar. It shall be stored in a water-proof shed with impervious floor and sides and shall be used quite fresh, that is within 14 days of the date on which it was drawn from the kiln. It must be entirely free from ashes, unburnt particles and other impurities. The lime for Tungabhadra Dam was burnt in country kilns of two different types. One was rectangular $25' \times 12' \times 6'$ and its operation was intermittent. The other was circular, 9′ in diameter and 15′ high and its operation was continuous. Surkhi is got by burning clay in the shape of balls or bricks.

Sand shall consist of hard, dense, durable, uncoated rock fragments and shall be free from injurious amounts of dust, lumps, soft or flaky particles, slate, alkali or organic matter, loam, mica and other deleterious substances. The maximum size of particles is limited to 3/16″. The sand shall be well graded with a fineness modulus ranging between 2.6 to 3.0.

Lime Surkhi mortar is ground in pan mixers. The grinding time is generally 30 minutes.

Cement mortar is mixed in concrete mixers to get a uniform mixing. The surkhi powder used to replace 20p.c. of the cement is got by powdering surkhi balls in disintegrators. The 1/80 mesh screen attached to the bottom of the disintegrators, gives the surkhi powder which satisfies the specification regarding the degree of fineness.

Placing Stones

The foundation surface is cleaned with an air and water jet before commencing masonry. A rich cement slurry of 1 cement : 2/3 water is laid on the rock and immediately a thick bed of mortar 2″ to 3″ thick of the same proportion as to be used on the masonry is laid. The stones are placed on this, well pressed and close together with minimum joints. Then further masonry proceeds. The following precautions are mentioned:—

1. Each stone before being used shall have their weak corners and their edges knocked off. It should be clean and wetted before use. In hot weather, it should be kept cool by being sprayed with water.
2. It should be solidly bedded in mortar. It is just shaken for this purpose. It should at the same time be pressed towards its neighbours without touching them and so that mortar joints could be a minimum. A hammer could be used for this purpose.
3. All the joints should be poked with a $\frac{1}{2}$″ rod about 2′ long so as to press it tight and to bring out the excess air. If the joint is thin, the trowel could be used for this purpose. When the joint is too big, clean spalls suited to the size of the joint shall be driven with a hand hammer of 4 to 6 lbs. weight. This avoids a thick joint of mortar and consolidates it at the same time.
4. No under-pinking should be done after a stone is laid, as this will leave air pockets.
5. No stone should be touching another without at least a thin layer of mortar between and if in the process of placing or dressing any stone or spall gets broken, the broken piece should be removed.
6. So that the masonry will act together, there should be no continuous joints either in a horizontal or vertical plane.

Added to the above, the following will be good rules to follow:

1. Lay the longest side of stone along the length of the dam. This makes the path of the percolation of water circuitous.
2. See no long continuous joints get formed across the dam.
3. Top surface of the dam during construction should not be smooth. The stones of one course over half the area at least should protrude halfway into the course above. In short, aim at a random rubble effect both in plan and section.

The masonry surface should be wire-brushed so that excess mortar, laitance etc. can be removed before another course is laid. Air jet is also used for removal of loose materials. When masonry is resumed after a considerable time great care will be necessary in preparing the old surface. Removal of dirt and set mortar will be found to be very difficult. The surface and mortar joints can be made fresh by using the chisel and hammer. Cement slurry is used just before laying fresh mortar and stone to get a good bond.

It is only the hearting of the dam that is in random rubble. The face work is preferably made up of heavier stones, laid in courses. This ensures a watertight work. In a medium sized dam as the Tungabhadra, watertightness is given a priority attention than even strength. For the maximum stress is in the order of 10 tons sq. ft. or 150 lbs′ sq. in. which cannot be considered to be very high.

It cannot fail to strike one who watches closely, masonry work being done by hand how the quality of work depends upon the individual mason and his conscience to do good work. As each stone has to be placed by hand and mortar pressed into

every void, the range in the quality of work can be vast. It is then one feels how it would be preferable to work with concrete where a good control over the quality of work can be had. At the same time, there is the feeling by placing good sized stones with mortar packed into every joint a more watertight work can be got than with the concrete. From all points of view for a dam of medium height, stone masonry seems to be quite suitable.

Contraction joints

Whether contraction joints are necessary in a masonry dam is a debatable point. The dam seems to be constructed so slow, that an easier and quicker dissipation of heat is expected and no shrinkage cracks need be anticipated. However, joints left at definite intervals seem to be a desirable feature in any construction. Also from construction point of view, this is very convenient. For example, in Tungabhadra Dam, work in certain lengths could not be proceeded with due to certain reasons, and here the adjacent lengths could be conveniently raised up commencing from the next contraction joint. In the same dam, in the cement mortar sections, contraction joints have been left at 93′-4″ intervals. The longest block in surkhi mortar section is 756 feet in length.

At the Tungabhadra Dam, the joint at the upstream face of the dam is sealed by the installation of annealed copper sealing strips of thickness varying from 1/8″ to 3/32″. It is U shaped so that it can open and close with joints. It is securely fixed in cut stone masonry on either side and for this purpose its ends are gripped at intervals and also provided with holes at 3′ centres through which $\frac{1}{2}$″ rods are passed. The U of the copper sheet is in a pocket provided in the cut stone masonry and this is filled with asphalt. A $\frac{1}{2}$″ steam pipe is installed in this pocket to reliquify the asphalt if necessary.

Touching up, curing, etc.

The cement we get from the Indian factories takes an initial set in not less than half an hour and a final set in not less than 5 hours. The surkhi mortar starts setting in about 12 hours time. It is seen that the latter also shrinks considerably as it dries. It has been found useful in the Tungabhadra Dam to press the shrinking surkhi mortar well into the joints before it attains its final set.

There is no need to emphasise that constant curing of the masonry work is necessary to complete the chemical action in the mortar and to enable it to achieve its maximum strength. Curing is generally done with water and in a masonry construction it is necessary to arrange for it non-stop.

Pointing

In a masonry dam pointing, especially the front face, is an important item of the work. For, if this is carefully done, the watertightness of the structure is bound to improve. At the Tungabhadra Dam this pointing was done with cement mortar of 1 : 2 proportion. The joint was raked for a minimum $2\frac{1}{2}$″ depth and thoroughly cleaned of any dirt or loosely adhering cement and washed out and thoroughly wetted with a jet of water under pressure. The mortar used for pointing was thoroughly rammed and caulked into the joints. Finally, the surface was finished smooth. The sand used for this work was fine enough to pass through a screen of 6 meshes to an inch. Pointing is done with the same care to the spillway face too.

Gallery

Galleries are provided in a dam for many purposes. Even through the best constructed dams, there may be some seepage and this has to be collected and let out. A drainage or a foundation gallery is formed for this purpose running close to the foundations. A drain runs on the floor of the gallery for gathering the seepage water. Vertical pipes from the foundations open into the floor of the drainage gallery. Similarly, vertical porous pipes built with the masonry of the dam, open on the roof of the gallery. All these are for collecting the seepage water and leading it into the gallery. The gallery floor and drain ought to have naturally a slope so that the drainage can flow. Triangular notches can be fixed at suitable places for measuring the flow. The drainage can be led out into the river or can be pumped out. The foundation gallery is useful for carrying out curtain grouting. A gallery is also useful for general inspection purposes. The Tungabhadra Dam has only one gallery running close to the foundations of size $5' \times 5'$ with a semi-circular arch over the same. This is of concrete with some reinforcement to take care of tension that can occur. A tram track has been permanently embedded on the floor of the gallery to enable drilling, grouting equipment, etc., to be moved. This was also useful in moving the steel shuttering for the roof from section to section.

Sluices

Sluices are essential in a dam to lead out the water for irrigation. In Tungabhadra Dam the size adopted was $6' \times 12'$. The sides and floor were lined with heavy cut stones and the roof was of reinforced concrete. Some steel was used all round to take care of tension that can occur round an opening in the dam.

The sluices had a bell mouth in front. There were grooves for dropping in an emergency shutter in the front and a regular shutter in the middle. A shutter well, a dry well and a hoist chamber were put up above the sluice to enable the operation of sluices.

Penstocks

Penstocks for power have also to be embedded

as the masonry proceeds. If they are of steel and if the dam is of stone masonry, naturally a certain thickness of concrete will have to be placed between the penstock and the masonry. Reinforcement is also provided to take care of any tension. The penstock has to be provided with a bell mouth at the entry which can be closed by a rectangular shutter. A trash rack structure has to be provided to prevent debris from entering the penstocks.

Gates

These are essential to regulate the water from sluices. They are also provided over the crests of the spillway to let out floods and store water as and when required. The gates used for sluices have to be designed for the high pressure they have to stand. They have to be provided with proper seals so that water cannot leak past them. Such seals are now-a-days provided in rubber and are fixed so that they are easily replaceable. The gates move on wheels which are kept either fixed to the gate or kept movable in a separate cage. Properly sealed roller bearings are provided to keep down the friction to the minimum. The sluice gates have to be operated from a hoist chamber above. Besides power, provision for hand operation in an emergency is also made. Devices for automatically shutting off power when the gates reach the bottom or a fixed opening are made. In the sluices provision for dropping another gate in front is made. This is necessary for the examination and repairs to the sluice or even the main gate. For the gates to slide in, the grooves are lined with cast iron or structural steel. These have to be fixed as the masonry construction proceeds. As it takes time to design and manufacture them, these will have to be arranged for promptly as masonry construction starts in the dam.

A unique feature in the Tungabhadra Dam was that all the sluice gates and hoists except for a few in the left flank were manufactured in the Tungabhadra Dam workshop itself. Usually the sluice gates are imported from other countries. Also welding was resorted to a good extent. The spillway gates which were $60' \times 20'$ were also manufactured at the site only. Here also a good deal of welding was done. The shutters were shop-welded and field rivetted. Possibility of manufacture in India, as seen in this case, has encouraged the Government so much that they discourage the import of shutters from outside nowadays.

Instruments

In modern dams, many instruments as thermometers, strain meters, stress meters, joint meters and plumb bobs are installed so that the behaviour of the dam when it is stressed can be studied. These studies are useful in improving on the design and introducing economies.

Finishing touches

A dam is sufficiently an important and imposing structure that architectural treatment to the same and keeping up an artistic environment cannot be neglected. The imposing gateway at the entrance to the Krishnarajasagar Dam in Mysore and the Brindaban Gardens below it attract innumerable visitors and cannot but give pleasure to them. A dam and its reservoir can easily become a recreation centre and in the United States, it is usual to take into account the revenue that will accrue from tourist traffic and the bird and wild life that the reservoir provides habitat for. In the Tungabhadra Dam, considerable time was spent in designing the parapet walls on the top of the dam and the Utility Tower. The circuit house on the top of the hill at the right flank with its verandah supported by the ornamental pillars of the Vijayanagar age and the view tower erected in front of it which give a panoramic view of the whole countryside cannot but soothe the eyes and the mind of the visitor. If poetically inclined, he is bound to acclaim the dam as a 'Poem in Stone'.

(Continued from page 2)

world make one doubt whether the world has at all become civilised. It may well be that the egos of wanton destroyers like Changez Khan and Timurlung have once again taken birth in this world with their hatred and love of destruction as strong as ever and with the advantage of modern weapons and equipment to help them in their nefarious task. Let us not forget that the beautiful and well organised irrigation system of ancient Persia was wantonly destroyed by an invader for the mere sake of destruction. Nearer home, the beautiful Vittal temple at Hampi which took 80 years to construct could never be utilised, because the country was overrun by invaders before the diety could be installed for regular worship.

I am not a pessimist. Even the partial completion of the Tungabhadra Project has been a great achievement for which all concerned deserve the greatest credit. But, as stated at the beginning, we are now at a milestone when it is worthwhile taking stock of the situation with a view to determine our future course of action. And it is in that spirit that I have jotted down a few stray thoughts in the hope that they may prove of some assistance to our great leaders in whose hands lies the destiny of India.

Foundation Treatment in the Tungabhadra Dam

by K. R. RAJAGOPALAN B.E., A.M.I.E.
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A gravity dam is only as stable as the base on which it rests. The stability of the rock foundation constituting the foundation of the dam depends on the physical properties of the rock, the uniformity of formation and the presence of seams, fissures or other bodies of disintegrated unsatisfactory materials and the extent to which such inadequate characteristics of the geological structure may be corrected by known and feasible methods of foundation treatment. Comprehensive knowledge of the foundation characteristics is therefore a vital prerequisite to an intelligent design of the foundation treatment. This knowledge is obtained from a correct geological data which is based upon a careful examination of the site including a thorough investigation of the character of the rock and known or suspected bedding, faulting and jointing. These data should be supplemented by information obtained from exploratory drilling. The amount of essential exploratory work and the necessary foundation treatment will usually be governed by the character and condition of the foundation and the type of structure to be built. Large and costly structures necessarily justify a considerable expenditure on exploratory work, since economies in design and construction may be effected by the elemination of unknown and uncertain foundation factors.

FOUNDATION ROCK AT TUNGABHADRA DAM

The foundation bed rock at Tungabhadra Dam consists mainly of two different types, epidiorite and pegmatite. The major portion of the foundation is hard black epidiorite while the rest is pegmatite of red and white varieties. Even in epidiorite formations there have been a number of places where pegmatite intrusions exist. The planes between epidiorite and pegmatite are tight everywhere and can be said to be almost blended with each other. The epidiorite rock has generally an upstream dip varying from 30 degrees to 50 degrees, while pegmatite formations are generally flat bedded. While epidiorite rock is very compact and hard though stratified and jointed in a few places, pegmatite formations especially of the white variety are highly fissured containing lot of quartzite, black mica and clay seams. Those clay seams are found to exist in horizontal fissures of varying thicknesses at different depths except in one or two places where vertical seams were also met with. The epidiorite rock is very heavy having a specific gravity as high as 3.6 while pegmatite is comparatively lighter with a specific gravity of about 2.65.

FOUNDATION TREATMENT

Foundation treatment usually consists of blanket or consolidation grouting, cut-off or curtain grouting or both.

Blanket grouting is accomplished by drilling and grouting a grid of shallow depth holes over an area extending from the axis to the heel of the dam before concrete or masonry is placed on the rock.

Cracks, crevices and fissures are usually more prevalent in the near surface rock than they are at greater depths and the blanket grouting therefore consolidates the natural foundation material making it more uniform and capable of supporting greater loads by filling up the cracks and faults.

Low dams founded on good rock may require no other grouting than blanket grouting to seal the fissures caused by stripping operations.

The cut-off grouting on the other hand creates a watertight zone or cut-off curtain beneath the dam in order to reduce the percolation through the foundation and thereby reduce the uplift on the dam. This deep cut-off is accomplished by either a single or a multiple line arrangement beneath the dam. A single line of closely spaced holes will usually provide a satisfactory cut-off for low dams or dams of medium height built on reasonably tight rock while the latter method provides a wider spread of grout with attendant strengthening of structurally weak rock over a greater area. In so far as impermeability is concerned a single line of closely spaced holes is believed superior to two or more lines of widely spaced holes.

The order of grouting is a matter on which engineering opinion is divided. All agree that blanket grouting should precede the placement of concrete. Whether cut-off grouting should precede concreting, whether the upstream or downstream line or a two line arrangement should be grouted by stage

or full depth methods are all still controversial problems.

It is generally considered that curtain grouting should be postponed till after the placement of concrete. The weight of the super-imposed structure undoubtedly permits the use of higher grouting pressure which in turn makes possible the injection of grout of lower water cement ratio.

Postponing curtain grouting until after concrete placement will necessitate construction of a grout gallery. Although an added expense, a gallery is an essential feature of modern dams apart from its utility in curtain grouting. This gallery follows the alignment of the main curtain for its entire length a few feet above the average rock surface. This type of construction provides freedom from outside interference during the grouting programme. Unlike other phases of construction rock grouting activities are not amenable to rigid time schedules. Each hole is a separate item which may require an hour a day or a week to complete. This uncertainty tends to disrupt the general construction programme. Perfection in grouting may not then be obtained during construction. It is also likely that after the completion of the work, filling up of the reservoir may point out the need for supplemental grouting. Should such a contingency ever arise further operations are greatly facilitated and the quality of the work improved, if a gallery has been included in the general lay-out.

GROUT HOLE DRILLING SIZE AND SPACING

Since drilling of holes constitutes a major item in any rock grouting programme the size and spacing of grout holes present a problem of primary importance. The cost of such drilling is ordinarily influenced by the diameter and depth of holes. This is particularly so when diamond drilling is resorted to. It is inferred from different observations that the quantity of grout that can be injected depends more upon the structure penetrated than it does on the diameter of the hole drilled. Other conditions being equal, it may therefore be taken that the most desirable pattern is one which will provide the maximum number and therefore the closest spacing of holes regardless of the diameter.

The holes for grouting in Tungabhadra Dam are drilled along lines parallel to the dam. For consolidation grouting, there are two lines of holes in the non-spillway and three lines of holes in the spillway section. But the number of lines are increased depending on the actual condition of rock met with in various reaches. The holes were drilled 20 feet into rock at 20 feet intervals, the holes in one row being staggered with those in the adjacent row. In places like L.S.900 to 1390 where bed rock was found to be highly fissured and withered it was found necessary to strengthen the foundation considerably. Holes were drilled here at 10 feet intervals, the distances of the lines being, 2, 12, 22, 32 and 42 feet from the axis and the depths however remaining the same 20 feet. In addition to these, holes were also drilled, wherever joints were visible and did not cross the above patterned drill holes.

Drilling Equipment, Out-turn and Cost Data.

These consolidation grout holes on the Tungabhadra Dam were drilled with diamond drills, calyx shot drills and wagon drills. The following numbers and types of drills were used:

Two Sullivan drills (H.D.16 and H.D. 22)

One G-4 Calyx drill.

Two H-3 Calyx drills.

Seven Wagon drills.

The different sizes of calyx holes drilled are $2\frac{1}{2}''$, $3\frac{1}{2}''$ and $5\frac{1}{2}''$ yielding cores of $1\frac{1}{2}''$, $2\frac{1}{2}''$ and $4\frac{1}{2}''$ respectively. Diamond drilling was rather expensive and uneconomical for the type of rock met with here. But the average daily rate of drilling was much greater than with calyx drills. Most of these low pressure grout holes were drilled with wagon drills using both forge sharpened steel and carset bits. The holes drilled with forge sharpened steels are of $3\frac{1}{2}''$ diameter at top and $2''$ at bottom. These result in the holes running to a taper. But in case of carset bits holes of uniform diameter are obtained from top to bottom. The different sizes of bits used are $1\frac{3}{4}''$ and $2''$. These bits have tungsten carbide inserts and were supplied by M/s. Ingersoll Rand Ltd. Drilling with forged steel is relatively slow, while carset bits were found very useful for quick drilling in hard epidiorite. A hole 20 feet deep could be completed in a day of 8 hours. These bits could also be sharpened with the help of a small handgrinder. The average life of the bit was found to be 100 feet in epidiorite rock and 200 feet in pegmatite. The average rate of drilling per day of 8 hours with calyx shot drills was 2 to 3 feet in epidiorite and 6 feet in pegmatite. The statistical particulars regarding drilling of low pressure grout holes in the Tungabhadra Dam are given below :—

With wagon drills.	..	11,681 Feet.
With calyx drills.	..	1,834 Feet.
Total depth drilled	..	13,515 Feet.

Epidiorite Rock Drilling

		per Rft.
With wagon drill	..	Rs. 3- 2-0 to 3-4-0
With Sullivan drill	..	Rs. 15-14-6
With H3 calyx drill	..	Rs. 11- 3-0

Pegmatite Rock Drilling

		per Rft.
With wagon drill	..	Rs. 2- 4-0
With Sullivan drill	..	Rs. 12-10-0
With H3 calyx drill	..	Rs. 9- 6-0

A careful operator could feel the existence of seams and fissures in the rock foundation as he drills; but in order to reduce the uncertainty attending the information obtained from him some new gadgets were obtained from abroad and used which serve as "feelers" for the purpose of locating seams or fissures and their thickness. These are called mechanical and electrical explorers. Their effectiveness is comparatively greater in smooth walled core holes than in rough walled holes resulting from wagon drilling and in either case it depends to a considerable extent on the experience of the operator and his skill in interpreting the indications he obtains.

GROUTING

Foundation grouting is defined as a method of forcibly injecting various liquid mixtures into the rock supporting engineering structures for the purpose of improving known or suspected imperfections. The grout may actually consist of any suitable liquid which solidifies after injection. Among these may be mentioned cement, flour, clay, asphalt and various other materials. A neat mixture of standard cement is considered the best grout for dams and this is what is generally used.

Grouting Equipment

Grout injection is accomplished by means of pneumatic displacement apparatus or by a pump. Each method has its own advantage. Injection by pneumatic displacement is accomplished by use of compressed air and a closed receptacle or tank provided with three openings: one for churning the tank with grout, one for introducing the compressed air into the tank, and the third for discharging the grout from the tank to the hole. The cost in this method is relatively low and this is preferable in some respects to pumps. It is these pneumatic grout machines that were used at Mettur Dam in Madras State for grouting. Grout pumps are however considered the ideal equipment for placing neat cement grout. Present day specifications prohibit placements by any other method. The pumps permit a close control of pressure and are so flexible that the rate of injection can be varied as desired.

The equipment used at Tungabhadra Dam consisted of the following components forming one complete unit:

(*a*) GROUT PUMP — This was a Gardener Denver Duplex double acting reciprocating pump operated by compressed air, size being $4\frac{1}{2}'' \times 10'' \times 10''$.

(*b*) GROUT MIXER — It consists of a horizontal mixing chamber and a mixing machanism which consists of horizontal propeller shaft and blades operated by an air motor.

(*c*) AGITATOR — This is an open drum with capacity of 14 cubic feet fixed with a vertical shaft with horizontal blades at the bottom operated by an air motor mounted on the top. This keeps the grout mix agitated before being forced into the hole by the pump.

Two such complete units were purchased for the Tungabhadra Dam and used in the grouting operations.

In addition to the above standard units, one Tridant water meter of $\frac{1}{2}''$ size recording in cubic feet with a totalling device for measuring the water used for mixing and pressure gauges graduated from 0 to 600 lbs, square inch for controlling and regulating the grout pressure were also used. At least two such gauges are connected to the grout system, of which one is located near the hole to indicate the pressure just before the grout is forced into the hole.

Grouting Procedure

The sequence of operations for foundation grouting is generally as follows :—

It is necessary first to remove clay and other loose and unsound materials from a seam before commencing grouting as the effectiveness of grouting will wholly depend upon the success achieved in removing all foreign loose particles from the seam. As soon as a grout hole is drilled a suitable size of G.I. pipe nipple about 3 feet long is fixed into the hole to a minimum depth of 2 feet and the hole is taken up for washing. Washing is generally done by a blow pipe having two-way connection at the upper end to facilitate alternate jets of air and water being blown through the hole. Normally water is pumped in the first instance for a minimum period of 20 minutes till the seam is washed which is indicated by the effluent being clear and free from clay or other loose materials. When this is effected alternate jets of air and water are successively used to wash out the seam thoroughly. When the position of any distinct seams or fissures are located by means of a mechanical or electrical hole explorer to secure an exceptionally tight seam each seam is isolated and washed individually by means of a "Double packer". After the hole is washed thoroughly it is tested with water by pumping water into it by a grout pump restricting the pressure to the allowable grouting pressure to be used later. This water test will give an indication of the tightness of the hole and the grout mix to be used at the same time revealing surface leaks if any.

Surface Leaks

When washing indicated leakage of grout at the surface the visible cracks or seams are caulked with lead wool and packed up with dry mortar or concrete using quick setting cement preferably.

Mix for Grout

The proper technique for successful grouting is the one which will permit the maximum injection of cement into the hole without displacing the foundation rock. Grout mixes are computed by volume and vary with thin mix of 20 to 1 to a thick mix of 2 to 1. As thin grout travels farther than a thick grout it is better to start with a thin grout of 1 in 20 to 1 in 15 and gradually thickened to 1 in 5 or 1 in 2 as the hole tightens. This procedure not only enables the grout to reach remote seams but offers a minimum of disturbance of the natural formation. For grouting it is necessary to use fine ground cement passing through 200 mesh sieve and in any case cement should be screened through 25 mesh sieve to take out lumps.

Grouting Pressure

The grouting pressure must be properly and carefully controlled to ensure against disturbance of rock structure from exposed rock surface. The highest possible pressure consistent with safety, speedy work and largest coverage should be used. Low pressure grouting with pressure varying from 70 to 100 lbs. is used for shallow grouting in the Tungabhadra Dam. For curtain grouting pressures varying from 150 to 250 lbs. have been used.

There are so many empirical formula given by different engineers for selecting the maximum pressures to be used which again involves so many coefficients and other variables influencing the allowable pressures. These will have a relation to the weight of super-imposed rock, water cement ratio of grout, previous grouting done in the area and weight of super-imposed structure, if any, resting on the rock.

Pumping Speed

Maintaining a constant pump speed is an important factor to be observed in efficient grouting. Sudden variation in pump speed blocks up the loose scales of cement adhering to the supply line and blocks up the hole. If the pump speed is too low the grout will tend to get set in the hole and the hole is lost.

Method of Grouting

There are generally two methods of grouting, viz. stage grouting and full depth grouting. There is also the consecutive grouting of holes in a line as opposed to the split spacing method of grouting.

(*a*) *Stage Grouting:* According to this a hole is first drilled to shallow depth and grouted. After the grout in the hole has set the hole is drilled deeper and grouted under higher pressures. This process is repeated until final depth is reached and the hole is grouted under the highest pressure. This method has its own advantages and disadvantages.

(*b*) *Full Depth Grouting:* This is the technique adopted in the Tungabhadra Dam being comparatively faster and more economical. The hole is drilled to the full desired depth and grouting done in one stage. When small seams crack or joints are revealed in the drill hole, though drilling is done to the full depth, grouting may be done in sections from the bottom upwards. This is accomplished by means of a "Stop" or "Packing Gland" inserted into the hole at any desired depth. This is generally called stop grouting.

(*c*) *Split Spacing Method:* Here a primary series of holes drilled at some distances, say 80 to 120 feet, is grouted. A second series consisting of an equal number of intermediate holes is then drilled and grouted at greater pressures than the first series. A third series may also be drilled, if necessary, thereby reducing the spacing to a quarter of that in the first series. In the case of curtain grouting in the Tungabhadra Dam it is this method that has been adopted, the final spacing of the holes being 40 feet and pressure adopted being 150 to 200 lbs. respectively for the primary and secondary series of holes.

Statistical Data and Observations during Grouting in the Tungabhadra Dam

For a total depth of 13,515 feet of low pressure holes grouted the quantity of cement pumped was 1274.4 cubic feet which works out roughly to one tenth cubic foot per running foot of hole. While grouting operations were in progress in the dam foundations there were quite a few holes that took in appreciable quantities of grout. They numbered about twenty. The maximum intake of cement for a single hole in the dam was 175.4 cubic feet. This was a test hole drilled at L.S. 2040 in epidiorite rock near the old Raya channel course. The dip in this case was towards the upstream side as usual and no defects could be seen in the foundation all round on a superficial examination. No surface leaks even were noticed during grouting. All the cement injected into the hole had travelled beneath the foundation bed and also to high elevations of the Raya channel bed as revealed when the excavation of the Raya channel section was taken up later. Another such hole was at L.S. 1563 in pegmatite rock. The rock foundation was flat-bedded and highly micaceous. For the naked eye the exposed rock surface appeared quite sound. When a number of holes were drilled and tested with air

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Tungabhadra Project Distribution System & Ayacut Localization

by N. HANUMANTHA RAO, B.E.,
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AS against projects in last century and early decades of this century for supplying water for irrigation of rice crop the idea of irrigating dry crops like jowar, bajri, cotton, pulses etc., gained ground under the Tungabhadra Project. Mr. Mackenzie in 1909 visualised a purely wet ayacut under the scheme with patches of wet blocks dotted over the area with long length of channels running through unlocalised stretches to irrigate them. Mr. Ireland in 1929 for the first time brought in the systematic irrigated dry crop over wide area into prominence. Mr. N. Parameswaram Pillai in 1933-34 and Mr. M. S. Thirumala Iyengar in 1941-42 followed the idea and set out the pattern of the ayacut placement in the cultivable command. To the predominantly dry ayacut, he placed a few blocks in the upper reaches under perennial zones and single crop wet zones.

IRRIGATION OF DRY CROP

Problems

In the wake of intensive study of the scheme of irrigating dry crop, a variety of problems catalogued below confronted the engineer, the agronomist, the economist and the revenue administrator. They all felt the need for coordination of their efforts, experiences and studies to bring out a practical and sound water regulation system.

(1) Soils and their reaction to systematic irrigation, classification and study of soil profile in the project area; (2) existing agricultural and irrigation practices; (3) seasons and crops; (4) utilisation of normal rainfall and supplementing it by irrigation; (5) the reaction of (the so-called) dry crops like jowar, bajri, wheat, cotton, pulses, groundnut, chillies, vegetables and fruit trees to systematic irrigation and the optimum water requirement of each variety.

Solutions

Solution of the above problem was achieved by systematic soil survey under categories like: light and heavy—red and black—shallow and deep—with or without any gypsum—salt laden or free from salt, conducted in 1933. In 1934 the experimental research station was started at Siruguppa applying Tungabhadra water to soils representative of over 80% of the soil predominating in the project area. It has produced very interesting results and a large volume of details on the problems noted above and a host of allied problems. The inches of wetting, crop period, total number of inches of wetting per acre for each crop grown and studied on the farm, have all been recorded. Duties with and without rainfall were also worked out. As the whole operation on the farm was done by Government and expenditure met with from Government funds, the economies of farming might not be attractive to any private farmer unless it is profitable. To satisfy the farmer's curiosity the Government started a farm at Bhagavadi near Siruguppa where the ryots themselves did the farming under the guidance of agricultural department. The localisation under the Tungabhadra Project has been circumscribed by the results, researches and advice of the Agricultural Officers of the farm.

Before going further into the details of localisation of ayacut and describing the distribution system, the following broad limits we had to work under are enumerated:

1. The gross storage in the reservoir.

2. The losses due to evaporation in the reservoir water spread.

3. The net storage in the reservoir.

4. The net annual draw from the reservoir that comes to the share of the low level canal ayacut.

5. The losses in transmission in the canals and distributaries are to be assessed to arrive at the net quantity of stored water that goes to the fields for irrigation of crop. A loss of 7.5 cusecs was taken as losses for million sq.ft. of wetted surface.

6. Each million cubic feet of net storage can irrigate about 20 to 25 acres of dry irrigated crops as enumerated above, or 4 to 5 acres of rice crop of 153 days duration, or $2\frac{1}{2}$ to 3 acres of sugar cane crops of 12 months duration (as finally worked in the Siruguppa research station.)

7. The agricultural practices in the project tracts fix two crop seasons viz., the Mungari (early June to end of September or middle of October) and the Hingari (early October to end of February or middle

of March). This depended on the rainfall in the tract and the soils obtaining, the light and red soil taking to Mungari crops and the heavy black soils taking to Hingari crops. Over 80% of the project tracts are of the heavy black soil types.

8. With assured supply the project officer sought to do away with the rain controlled Mungari and Hingari seasons but nevertheless divided the cropping season from June to March (9 months) with 2 seasons of the early and the late, each of about 4½ months duration with about a fortnight overlap in middle of September to middle of October each year. The ayacut reckoned in the project is the extent covered *by a single crop in only one season.* A study of the project area, the economy of the cultivation and the intensity of the population of the tracts led *to a decision that not more than half the area will at any time require water for irrigation,* while total ayacut worked out is the total of the areas irrigated in both the early and late seasons. This connotes that the whole distribution system is designed to irrigate only half the area localised at any one time. This is the bed rock on which the localisation has proceeded. Each block localised is thus further sub-divided into an early irrigable portion taking water from June to middle of October and the other block taking water in the late season from middle of October to middle of March. Equity is sought to be achieved by the early block this year taking water in late season next year so that any one block may not have to restrict itself to one season for all time. The cropping schemes has also been devised by the Agricultural Department to be such as to fit in with the scheme of irrigation of pulses, redgram, groundnut, and bajri (Korra) in early period and cotton, jowar, chillies and garden crops irrigating in the later period.

So far everything goes quite smoothly. But the Agricultural Officers of the Siruguppa farm struck a warning note that irrigation of dry crops in the night is not a practicable proposition for the following reasons :—

1. The crops grow high enough and the irrigator cannot judge the intensity of irrigation.

2. These crops are very sensitive to application of water requiring not more than 2", once each fortnight. A little over-application causes the crops to wilt and a little under-irrigation causes the same to wither.

3. Irrigation is to be carried on as per the bed or ridge and furrow system and water more or less carefully piloted to the several furrows and immediately the irrigation is completed, switch the water on to another block.

4. Irrigation of dry crops involves drawing fractions of a cusec and control of irrigation in terms of inches of water is only possible by adjudging time of application.

This contingency posed a problem to the engineer. He built up the thesis of irrigation of dry crops by day covering 13 hours of the day and the same water is to be turned to a wet block of calculated extents for the balance 11 hours of the night, thus disturbing the function of main distributary network to the minimum. It was worked out on the basis of actual wettings of dry and wet crops, that every cusec of flow in the distributaries and laterals localisation of 50 acres of wet crops *i.e.*, 25 acres in early season (June to middle of October) and 25 acres in late season (middle of October to March) and 160 acres of dry crops (80 acres in early season and 80 acres in the late season).

Pattern of Localisation and Limitations

The area on gross command is over 9 lakhs of which 7.5 lakh is cultivable, the balance being waste, rocky or sandy. The gross storage in the reservoir is about 65,000 million cubic feet for our share and the potentialities of this storage, after allowing for needs of existing irrigation in ancient channels and assistance to Kurnool-Cuddapah Canal, is computed at 58,000 acres of wet crop (including 15,000 acres of perennial crop) and 1,72,000 acres of dry crop *i.e.*, a total of 2½ lakhs of acres. This necessarily means that we have to discard 5 lakhs of acres of cultivable command without localisation. This problem was solved as per the following policy laid down:

Once the distributaries are laid on ground and the area commanded is delimited with drains and ridges clearly marked and the discharges prepared as per draw-off statement (fixed on an equitable basis with uniform intensity of irrigation), select the best plots village-war nearest to the valleys and work up to higher levels till total area required for the allotted discharge is arrived at. Stop the localisation at this, leaving belts of unlocalised plots hugging each distributary at the higher levels. In each block fix the dry areas at higher levels and the corresponding wet blocks taking the same water in the night in the lower levels near about drains so as to facilitate drainage and prevent water logging.

One restriction is to prohibit localising wet area within 4 furlongs from nearest village site, built up areas or Nathams as a preventive measure against malaria these tracts are habituated to. A picture of the whole scheme with all its limitation and stipulations as above set forth, is sufficiently complex to visualise. But this is the only system that clinched itself for adoption after mature consideration in a series of conferences of engineers, agricultural experts and revenue authorities from 1947 to 1955. The *modus operandi* of the actual process of localising is as follows:

(Continued on page 22)

The Tungabhadra Left Bank Canal

by P. R. NAYAK, I.A.S.,
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THE scope and pattern of development under the left bank canal of the Tungabhadra Reservoir bears features which can be clearly distinguished from the problems presented by the area commanded by the right bank canal. The two canals fell under the jurisdictions of separate States when the Tungabhadra Project was conceived and remained so until its execution was well under way. On the left bank was the famine-visited Hyderabad district of Raichur and along the right bank lay sprawling the four "ceded districts" of Madras State—Bellary, Anantpur, Cudappa and Kurnool which were well-known as scarcity tracts. While the course of economic history on both sides of the river, therefore, pointed towards the same urgent need—that of taking the waters of the Tungabhadra as far afield as possible, geographical features dictated different courses of execution of the project. The rolling countryside on the right bank permitted the extension of the canal for nearly 250 miles in three districts. The Krishna Valley, however, stopped the left bank canal at its 127th mile and squeezed the ayacut of nearly 6 lakhs of acres within the limits of one district, Raichur.

It is, indeed, possible to trace to this one circumstance an important difference in planning, implementing and developing the project on the two banks. The same quantity of water was available for distribution among three districts on the right side but only in one on the left. Consequently, while almost all land coming under the command of the left bank canal was "localised" for irrigation facilities, only scattered patches were selected under the right bank canal. If the cultivators were thirsty on the right side, water went abegging at first on the left and the development of the area in general and the utilisation of water, in particular, lagged behind the right side. There are, no doubt, other factors contributing to the discernible difference in the pace of development on the two banks. The cultivators of the ex-Madras area were already irrigation-minded and a number of tanks and wells existed even before the commencement of the project, but Raichur district of ex-Hyderabad State was a sadly neglected district steeped in poverty, ignorance and backwardness. The density of population on the right side is about 25% more than on the left and the holdings are smaller permitting greater employment of human and material resources. Bellary city and Hospet town are important trade centres within easy reach of the cultivator on the right bank, while no comparable activity is apparent in Raichur district. A sugar factory of the capacity of a thousand tons working in Hospet for the last many years has stabilisied the agricultural economy on the right side and the recently erected co-operative sugar factory at Kampli has added to its prosperity. On the left side, however, a sugar factory of an uneconomic capacity has been limping along with great trouble to itself and to the cultivators and the proposed co-operative sugar factory at Gangawati is still only a forlorn hope. It was not without sufficient reason, therefore, that the Planning Commission gave a deserved place to the Raichur side development schemes in the Second Five Year Plan and ear-marked an amount of Rs. 2.25 crores for their rapid execution.

A PROTECTIVE PROJECT

The main canal on the Raichur side is designed for a discharge of 7,000 cusecs at the head sluices. After the Sanapur subsidiary reservoir at mile 14 of the canal the discharge is reduced to 3,800 cusecs. The canal is to run a length of 127 miles feeding about 100 distributaries and irrigating portions of five taluks—Koppal, Gangawati, Sindhnur, Manvi and Raichur. The gross command of the canal is 8,00,000 acres and the net irrigable command is 6,60,000 acres. Having regard to the share of water alloted to the Raichur side and also remembering that the project is primarily a protective measure intended to serve as large an area of the scarcity tract as possible with the facilities of light irrigation rather than to confer the benefits of intensive irrigation on a limited area, about 7/8th of the irrigable command, that is, an area of 5,80,000 acres has been "localised" for irrigation.

THE LOCALISATION SCHEME

In order to ensure economical, judicious and gainful use of the water available for this area of 5,80,000 acres, the Mysore Government have sanctioned the following cropping pattern:—

Aby paddy	50,000	Acres
Tabi paddy	10,000	„
Sugarcane	15,000	„
Khariff	2,00,000	„
Rabi jawar & cotton ..	2,75,000	„
Garden	30,000	„
Total	5,80,000	„

The successful development of the ayacut on proper lines keeping the above cropping pattern in view depends to a great extent upon the strict observance of the scheme of 'localisation' of lands. 'Localisation' means location of lands for different intensities of irrigation and fixing up of blocks separated by natural drainages for various light and heavily irrigated crops depending upon topographic situations, drainage conditions and inherent properties of soils and isolation of lands unfit for irrigation. Unplanned irrigation brings in its wake manifold problems such as water-logging, development of alkalinity of the soil and unsanitary conditions in villages. A detailed field to field soil survey was conducted by the soil chemists and detailed maps of blocks are being prepared distributary-wise. Distributaries are designed and excavated on the basis of these plans.

PROGRESS OF IRRIGATION

Water was let out in the main canal on 1st July, 1953 for the first time upto mile 10 of the main canal. In 1957-58 about 35,000 acres became available for irrigation and an area of about 28,000 acres was irrigated. The area provided with irrigation facilities reached 70,000 acres at the beginning of the khariff season of 1958-59, but the area actually irrigated lagged far behind, at about 33,000 acres. This partial achievement focusses attention on some important problems which demand serious examination.

IMPEDIMENTS TO PROGRESS

Attempts to develop the ayacut under the Tungabhadra Project both under heavy and light irrigation have brought to light the existence of certain major impediments to the quick development of the whole ayacut of 5.8 lakh acres envisaged in the Second Five Year Plan. These difficulties may broadly be divided into two categories: (1) difficulties in developing lands under light irrigation, and (2) difficulties in developing lands under heavy irrigation. These two difficulties have been separately categorised as they have some distinctive features although there is a common pattern of deficiencies and draw-backs applicable to the whole ayacut covering both heavy and light irrigation.

Development of Light Irrigation

It has been pointed out above that the Tungabhadra Project is primarily a protective measure. Out of the 5.8 lakh acres localised for irrigation as large an area as 4.75 lakh acres has been set apart for the cultivation of light irrigated crops like khariff and rabi jawar, khariff and rabi groundnut, cotton etc., and an area of 30,000 acres has been ear-marked for garden cultivation which is also classified under light irrigation. The cultivator in the Tungabhadra area does not understand light irrigation. His fancy is always for the heavy irrigated food crop like paddy or commercial crop like sugarcane. In the nature of things obtaining, however, only a limited area of 75,000 acres has been localised for heavy crops. It is necessary to convince the cultivator that the mere irrigation of dry crops can increase the yield by nearly 100% and that the application of optimum quantities of chemical fertilisers can increase the yield by 400%. He is also to be educated in the relative advantages of irrigating dry crops in terms of the comparatively less labour required and the smaller cost of cultivation. Government, of course, have been quick to realise the need for educative propaganda in the field. Demonstration plots numbering nearly 2,000 of all kinds of light irrigated and garden crops have been established in 1958-59 and each village has been served by demonstration plots of crops representative of that village. Also, in order to popularise the light irrigation of dry crops a selected number of progressive farmers in each village have been induced to cultivate these crops intensively in one or two acres of their holdings. If these farmers successfully cultivate their lands in the manner recommended by the Agriculture Department, they will have opened up a vast field for further development of light irrigation during the coming years. Besides, batches of selected farmers are being taken round on a study tour to government and private farms in and outside the district, *e.g.*, to Mandya and Bellary. Farmer's training classes, Farmer's Days and Cattle Shows are being organised; audio visual exhibitions are being arranged.

Development of Heavy Irrigation

Sugarcane: In the taluks of Koppal and Gangawati an area of 17,535 acres has been localised for paddy and 17,800 acres for sugarcane. The sugarcane area of about 3,000 acres in Kopal has been completely developed. This quick development may be taken to be entirely due to the existence of a sugar factory in Munirabad. Gangawati taluk, however, does not enjoy the privilege of possessing a sugar factory which can crush the cane expected to be cultivated in about 15,000 acres. About 3,000 acres were cultivated with sugarcane in 1957-58 in Gangawati taluk. The experience in disposing of this cane has, however, been very sad and agriculturists have incurred considerable losses. Until a sugar factory is established in Gangawati there will be little scope for the development of the sugarcane

area. The promoters of the Gangawati Cooperative Sugar Factory have sold 9,500 shares of Rs. 50/- each and have collected a sum of Rs. 1,05,000/-. The big target of collecting the required share capital of Rs. 8,00,000/- has remained a distant hope, only mainly because of the difficult foreign exchange position. But there is little doubt that no sooner the Central Government licenses the factory than the required share capital and more will be collected.

Paddy: Government have permitted the cultivation of paddy or other light irrigated crops in sugarcane lands until the establishment of a sugar factory. There is now a trend towards such conversion but the problem of mobilising enough labour is staring every cultivator in the face. It is estimated that there should be at least two adult labourers for every acre of heavy irrigated land. Unfortunately, the present position of availability of labour in the ayacut is very unsatisfactory.

SHORTAGE OF MAN-POWER RESOURCES

Raichur district is sparsely populated, continued drought-affected conditions being one of the major causes. The density of population is about 160 per sq. mile whereas twice this density would be necessary to meet the damands of irrigated cultivation on such an extensive scale. The experience of the last two years would show that in some cases large areas of heavy irrigation can remain undeveloped for the only reason that there were not enough men to work on them.

LARGE HOLDINGS UNDER IRRIGATION

The Localisation Scheme also has adversely told upon this situation. Under the principles of soil classification followed in the localisation of land, a close adherence to a uniform distribution of land for light and heavy irrigated crops in all villages or among all cultivators in a village would be difficult; and it has happened in a number of villages and in the case of nearly all individual cultivators that large blocks of land localised for heavy and light irrigation fall within the limits of villages or the holdings of individual cultivators incapable of developing such lands without an appreciable increase in the man-power resources of the village. Nevertheless, this problem has to be met not by changing the localisation scheme, but by augmenting the man-power resources of the area as a whole and by legislation to absorb the irrigable surplus holdings of cultivators by the imposition of Betterment Levy in the shape of land and to allot such surplus land to persons imported from other areas.

IMPORT OF LABOUR

While the position with regard to the Betterment Levy is not clear, a scheme for importing 500 families of agricultural labour is being implemented. Families have arrived from Bijapur and North Kanara and other districts of the Mysore State and they are being offered some attractive facilities like:

1. Two acres of dry land or one acre of irrigated land—available government land being given free and the cost of acquired land allotted being recovered in instalments.
2. Free allotment of 5 guntas of land for house building.
3. Free grant of Rs. 50/- for house-building materials.
4. Development taccavi of Rs. 100/- per family.
5. Loans for the purchase of bullocks.
6. Loans for the purchase of agricultural implements and cattle fodder at the rate of Rs. 50/- per family.
7. Free transport from the old residence to the new village.

It is gratifying to note that the imported labour families have settled down in their new surroundings.

DEVELOPMENT TACCAVI

Raichur being a famine-stricken area, the people are mostly resourceless. It is impossible for them to develop lands without any initial aid either from government or from any other agency. Government, having given serious thought to this problem, have launched upon a scheme to advance liberal taccavi loans for the development of lands since 1955 and so far an amount of Rs. 22,01,178/- has been advanced. Taccavi at a flat rate of Rs. 300/- per acre of land localised for sugarcane, Rs. 200/- for paddy and Rs. 100/- for light irrigation is being advanced.

Seasonal Finance

Development taccavi launches the cultivator on the road to development but he should keep moving with the aid of seasonal finance. The full development of the area both under light and heavy irrigation in terms of maximum production cannot be realised until the cultivator avails himself of all the resources placed at his disposal. Unfortunately the cooperative movement in the Tungabhadra ayacut is in a primitive state of development. People are not conscious of its benefits and inspite of intensive efforts it has been hard to convince them that under assured conditions of water supply they would greatly profit by availing themselves of short-term loans repayable within one year, as there would be no danger of crop failures. The cultivators, however, prefer long-term loans repayable in 10 to 15 instalments. It has been the experience of the last two years that the first step towards the improvement of the situation is wide-spread and intensive propaganda in the villages. A concentrated drive has been undertaken by all the development agencies in the project, like the Cooperative Depart-

ment, the Revenue Department and the National Extension Service and the results are encouraging. Short-term loan applications amounting nearly to five lakhs of rupees were collected within a space of three months and forwarded to the Cooperative Bank for sanction. Ten large-sized cooperative societies have been established to cater to the short-term needs of the cultivators. Godowns for each of these societies are being constructed. A cooperative marketing society has been registered in Gangawati and three sugarcane processing cooperative societies have also been organised for the manufacture of jaggery.

Nevertheless, the organisational difficulties in the system of short-term credit in the ex-Hyderabad area should not be under-estimated. The valuation of lands is very conservative being dependent upon the valuation of lands for the purpose of sale under the Tenancy Act. A wet land can be valued only at 24 times the assessment of the land. A paddy land, for instance, assessed at Rs. 12/- per acre could be valued at a miximum rate of Rs. 288/- per acre and if the loan limit is taken to be 80% of the valuation, an amount of Rs. 230/- may be advanced as loan on a paddy land. Development taccavi of Rs. 200/- is usually advanced on paddy lands and there would thus be a margin of only Rs. 30/- per acre for short-term credit, whereas a minimum of Rs. 150/- per acre is necessary to meet the cost of seed, fertilisers and seasonal operations.

An attendant question is that of advancing short-term loan on crops to non-owners of land. The existing rules do not permit advance of loans to tenant-cultivators unless they produce two sureties with unencumbered land. The latter condition is difficult to fulfil, especially in the already developed sugar factory area of Munirabad where more than 50% of the cultivators are tenants. A system should be evolved whereby the tenants may be advanced crop-loans on the security of two sureties who need not necessarily own unencumbered land.

ANIMAL HUSBANDRY

In our economy of to-day bullock-power is in importance next only to man-power. Raichur district is seriously lacking in bullock-power also. At present during the seasonal operations, some animals from the non-commanded area are temporarily imported but this cannot meet the growing requirements of the area. Bullocks have to be imported, but more important appears to be the task of upgrading the cattle-wealth of the area and of ensuring a regular local supply of good seedbulls to promote such upgrading. This is no doubt a long-range development scheme and the Veterinary Department is already siezed of the situation. A cattle-cum-sheep breeding farm was established at Munirabad four years ago. It has a foundation stock of about 100 Krishna Valley cows and four bulls. Sixteen Tharparkar cows have also been secured and a matching bull is being purchased. The farm has already started supplying seedbulls to the ayacut. Artificial insemination centres are proposed to be started at all taluk places. The Munirabad Farm and the veterinary hospital at Gangawati have already been equipped with artificial insemination apparatus.

RECLAMATION OF LANDS

A mechanised unit consisting of 2 bull-dozers and 4 tractors for the purpose of reclamation of lands functioned last year under the supervision of the Agriculture Department. A similar unit of machinery worth about Rs. 13,50,000/- was purchased by the Director of Agriculture, Government of Hyderabad from the Tungabhadra funds but it is now lying at Hyderabad. The machinery now in the ayacut cannot fully meet the demand for tractor-ploughing and bull-dozing.

HORTICULTURE

With 30,000 acres of land localised for garden, horticultural development on proper lines assumes immediate importance. It is the experience of the last two years that very few people take to garden cultivation, firstly because of the lack of knowledge of horticulture and then also due to the time lag between investment and return. It was only in the middle of 1957-58 that the horticulture department commenced its activity. An orchard-cum-nursery is proposed to be established. In all villages in which land has been localised for garden, demonstration plots of coconut, mango and other miscellaneous fruits have been laid out, each on an acre of land. Vegetable gardens are encouraged with free supplies of seeds. Demonstration plots of different vegetables have also been established. Glyricidia rooted cuttings and seedlings are raised and supplied. A considerable amount has been disbursed as garden taccavi against which fruit plants will be supplied to cultivators.

PISCICULTURE

The fish-wealth has also to be exploited and interest of the population aroused in fish-culture. The Pisciculture Department has established ponds and aquaria at the damsite where fingerlings collected in the river are stocked, reared and liberated in rural tanks and wells in the ayacut area. The popularisation of fish culture which assumes importance with the advent of irrigation facilities, can help to ease the pressure on food grains.

AFFORESTATION

Raichur district has no forest except on the hillocks of Gangawati and Koppal taluks under the Tungabhadra Project. In the plains there are not enough

trees even for shade and shelter. Fuel for domestic consumption is a problem. Afforestation has to be given its proper place in the development. There are no large tracts of government lands suitable for afforestation but some small blocks of about 100-150 acres at Marli, Kuntoji and Mushtoor have been handed over to the Forest Department, on which afforestation work is going on. These small blocks of afforestation will in course of time be handed over to the Panchayats for maintenance and utilisation. A two feet contour belt on the foreshore of the reservoir is also being afforested with suitable species.

DEVELOPMENT ROADS

Adequate means of communication are an important factor in the development of irrigation. The present cart-tracks are all low-lying and will get flooded with the advent of irrigation. The replacement of such tracks with arterial and internal roads properly aligned will be necessary to ensure easy transport of seeds, manure and produce to and from the lands and from village to trade centres. Development roads of a total length of about 260 miles in Koppal, Gangawati, Sindhnur and Manvi taluks have been proposed. The work of construction is in progress in Koppal and Gangawati taluks. Surveys are being conducted in Sindhnur taluk and beyond. Two P.W.D. Sub-Divisions have been appointed for this purpose. About a 100 miles of internal roads per taluk will also have to be constructed to serve large blocks of heavy and light irrigated areas.

AGENCIES OF DEVELOPMENT

A large number of officers of the several development departments of government have been specially appointed to accelerate the pace of progress in the Tungabhadra area of Raichur district. The Divisional Commissioner, Gulbarga has been designated as the Administrator of the Project and exercises power of direction and general control over the various development schemes and the staff executing them. An annual consolidated budget proposal is submitted to government for sanction after the individual schemes are examined by the respective Heads of Departments, scrutinised by the Administrator and approved by the Tungabhadra Advisory Board which consists of non-officials and all officials working in the project.

In a development scheme of the size of the Tungabhadra Project in which so much is attempted to be done in so short a time, it is patent that coordination between all arms of the developmental set-up is the very essence of progress and co-operation, its soul. It is unimaginable that whatever success we may have been able to achieve, would be possible, were there not so many persons, officers and men in public life, who willingly gave their all in terms of sympathy, understanding, enthusiasm, co-operation and active support. In Raichur to-day one meets the broad and heart-warming vision of men toiling shoulder to shoulder and moving towards the common goal of ensuring to the Tungabhadra people a place in a glorious future.

(Continued from page 17)

TUNGABHADRA PROJECT: DISTRIBUTION SYSTEM AND AYACUT LOCALIZATION

1. P. W. D. prepare plans to scale 16″ or 8″ to a mile of each distributary and area commanded by it. Fix the pipe boundary, note village S. Nos., extent of each such Nos., note the discharge for each pipe, fix the dry and wet areas to be localised and place them on the map, note contours. Uncommandable areas are hatched off. This plan noting pipes positions and a register noting ayacuts pipe-war and--village-war are prepared. These are sent to the Special Officer, (Revenue Department) by the Executive Engineer.

2. On receipt of these maps and registers, the Revenue and Agricultural Officers examine the areas conjointly and suggest any changes if necessary.

3. Differences of opinion between P.W.D., Revenue and Agricultural departments are cleared by discussions and joint field inspections if necessary.

4. This done, the plans and registers are finalised and signed by each Departmental Officers at a joint meeting.

5. Ayacut hearings are conducted in each village included in localisation by all the officers of the 3 departments after issue of notices of inclusion to each pattadar.

6. Then the publication of the ayacut localised is made in the Gazette.

CONCLUSION

This is a unique type of localisation attempted on this project and for the first time in the history of any irrigation project and is very intricate. Time alone will show up the wisdom or otherwise of the efforts of the persons who ventured on this type of localisation. But the uniqueness gives the charm to it. Legislative measures so far taken may be deficient leading to complication especially due to political changes that have come over the ayacut almost in the closing period of this localisation.

Tungabhadra Project
Low Level Canal Distributary System

by E. S. SASTRI, B.E., A.M.I.E.,
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THE Tungabhadra Project is a common scheme for the States of Mysore and Andhra Pradesh. The left side canal serves entirely Mysore State and the right side canal serves Mysore and Andhra Pradesh. From the irrigation point of view, it is in the main, a scheme to give relief to the famine-stricken and drought-affected areas of Rayalaseema. So as to give relief to as much an area as possible, the benefits of the project have been distributed along a long length of the canal. Each and every village covered by the canal being given a proportionate share of the benefits of water (for drinking water and irrigation needs). The intensity of population in the area is small and spreading the benefits of the project helps in providing full employment to all available labour without at the same time necessitating importation of labour on a large scale.

THE DRY-CUM-WET SCHEME

The crops that are grown in this area are cholam and korra, the main food crops and groundnut and cotton, the main commercial crops. The rainfall in the area is very low, average annual rainfall being only about 20". Even this is precarious, erratic and undependable. The project therefore was sanctioned for execution as a project for the irrigation of those dry crops, to stabilize them during periods of drought. For the study of the aspects connected with the irrigation of these dry crops, an agricultural research farm was opened at Siruguppa where the soil available is representative of the soils of the tract served by this project. One important result brought out of these experiments is, that in this area where the ground slope is steep (being about 1 to 1½%) irrigation of these crops has to be done with great care to prevent serious erosion. The quantity of water supplied also should be carefully regulated, as any excess irrigation will be harmful for the crops. Such careful irrigation is possible only during day time. And if night supplies should not go waste they should be utilised for irrigation by innundation *i.e.*, for wet crops. This resulted in a scheme of irrigation known as the "Dry-cum-Wet Scheme".

DUTIES ADOPTED

As a result of the experiments conducted at Siruguppa Farm, the following duties have been fixed for the wet and dry crops:

WET:	Early paddy: June to October,	60 acres per cusec. Base 150 days.
	Late paddy: September to January.	60 acres per cusec. Base 150 days.
DRY:	IRRIGATED CORPS:	Average duty adopted 150 acres per cusec.

The day irrigation is taken to be from dawn to dusk for 13 hours and night irrigation for the balance of 11 hours. This gives a duty of about 25 acres for wet and 80 acres for dry for one cusec in each crop season, with the hours of supply as noted above.

LOCALISATION OF AYACUT

As has already been mentioned earlier the principle of distribution of benefits of the project over a wider area has resulted in water not being available for the full commanded area throughout the length. So, only a part of the area is localised as the ayacut.

During earlier investigations, block levels have been taken for the entire area and 5 feet contour maps have been prepared.

With the available water, the total area that can be irrigated at the duties mentioned above, has been worked out and a proportion of this area to the cultivable commanded area is arrived at (cultivable area being arrived at from village records and commandability verified from the contour maps). In the area west of Hagari it works out to about 60% and east of Hagari about 33%. The entire area is divided into blocks bounded by drainage courses. The apportionment of ayacut in these blocks is based on the cultivable commanded area of each block and within each block, the ayacut is localised on the following principles:

1. Each village in the block shall have representation as far as possible proportionate to the cultivable commanded area.

2. The wet and dry blocks which are separate units shall have areas in the proportion of 50 and 160.

Pipe aqueduct for minor distributary.

3. No wet block shall be located within a radius of 4 furlongs from any village, so as to provide as a preventive measure against malaria.

4. As far as possible the lands localised shall belong to different people so that the benefit of irrigation shall be equitably distributed among as many land owners as possible.

5. Contiguous bits of more fertile fields are generally selected for the wet block.

6. The ayacut shall be located nearest and abutting the drainage courses so as to afford adequate drainage facilities and also to obviate water-logging of the fields at lower level.

7. Any field localised will get water for only one crop either early or late thus localising twice the area that can be irrigated in one crop season by the available discharge.

After localising the ayacut tentatively in the office, the lands are inspected by the P.W.D., Agricultural and Revenue Departments, each examining the area from their different points of view, the P.W.D. verifying commandability if the lands are cut up by minor vankas and to ensure that it is possible to supply water to each of these fields, the agricultural department taking care that the soil is really suitable for the type of irrigation proposed and the revenue department checking up the ownership etc.

THE DISTRIBUTARY SYSTEM

From the localised area the discharge required for each block is calculated at the rate of 1 cusec per 210 acres of total area localised. There will be one distributary common for both the wet and dry blocks bifurcating into two branches, the wet and the dry.

An offtake from the main canal carrying more than 10 cusecs is termed as a major distributary and if less as a minor distributary. The channel carrying water either from the main canal or a major distributary upto the fringes of ayacut is called a minor distributary. The water course with the actual ayacut area is called a "field channel". These are special definitions applied for this project and have no bearing on the discharging capacity of these channels.

Generally in all other projects the field channels are excavated upto the limit of 150 acres and aligned and land acquisition only done for field channels serving down to 25 acres limit; in this project it is laid down as a principle that the field channels shall be aligned and excavated (acquiring necessary lands also) so as to supply water to each survey number irrespective of its extents. The idea is to augment the development, as irrigation of any field need not wait for the co-ordinated effort of all the concerned ryots who are mostly poor and for whom irrigation is new. The control and distribution of water in the ayacut and the maintenance of these field channels is also the responsibility of the government.

FACTORS CONTROLLING THE ALIGNMENT OF DISTRIBUTARIES

The most important factors controlling the alignment of the channels would be the difference of elevation of the low water level in the main canal and the level of the highest field served; the distance of the fringe of the ayacut from the offtake and the nature of the terrain traversed. In the case of this project, by virtue of the fact that the ayacut localised is nearest to the drainages and the intensity of irrigation is only in the order of about 33% the ayacut is generally far removed from the main canal. As the general ground fall is rather steep, the difference of elevation between the L.W.L. in the main canal and the highest point of the ayacut is generally very large and in some cases even upto 150 feet.

The main canal negotiates ridges by short deep cuts instead of going by circuitous contour line. The offtake being located at a point where the canal is in full depth of cutting, the distributary has to run along contour until it catches up the ridge. From this point it is aligned as a ridge channel.

Another typical core wall drop on major distributary.

Core wall drop for 3 to 5 cusecs.

The minor distributary takes off at a suitable point from the major distributary and is aligned as far as possible along the minor ridges.

The area is very badly cut up and there are, in a good number of cases, many mounds connected by low saddles and no defined and continuous major ridges. In all such cases the level of the saddle controls the alignment in the lower reaches and a distributary, which has run for certain length along the ridge, would suddenly change over to a contour channel beyond the saddle.

The channels are to be as far as possible straight and where curves (bends) are inevitable they should be very smooth, allowing a minimum radius of curvature of 50 times the bed width. (The curves in channels carrying less than 5 cusecs may be aligned by merely marking out on site. No special curve ranging is necessary for them.)

All major and minor distributaries are mostly taken in full depth of cutting to avoid unauthorised irrigation by cutting up the banks and also to safeguard against the possibility of breaches.

As far as possible, all vanka (drainage) crossings shall be provided with masonry crossings. A loss of head of about 0-2 feet may be allowed at these crossings limiting the velocity to 3 ft/sec., in the barrel.

Where drainage crossings became necessary it has to cause least interference to the drainage courses. So, a canal syphon is to be preferred to an under-tunnel. In case of syphoning also, in order to prevent undue depression of vent and consequent silting up and also to prevent leakage of canal water into the drainage course, it is necessary that the channel crosses the drainage with a minimum of 2 feet, cutting at the deepest bed level of vanka wherever possible.

THE METHOD OF INVESTIGATION

(*i*) The first thing to be done for fixing the alignment is a general reconnaissance of the area through which the distributary is taken and fixing the point where it should catch the ridge. Levels are taken along with the fringe of the ayacut and highest points fixed.

(*ii*) From the offtake from the main canal, one supervisor takes probing levels and fixes the approximate contour line. Behind him a surveyor measures out the length and fixes the mile and furlong points, approximate points etc., and transfers the line on to the village plans by identifying the survey numbers and measuring the distances from the survey stones to salient points on the alignment. Behind him, another supervisor takes L.S. and C.Ss., (L.S. points at 110 ft. intervals and C.Ss at every furlong for 330 ft. on either side). This would incidentally serve as a check for the levels. As soon as the ridge point is caught the alignment becomes easier and no probing levels will be necessary except as a check and this check is confined only for the major distributaries.

(*iii*) Field Channels. At the outset, the ayacut blocks are to be separated into three categories: (*a*) ayacut blocks of 50 acres and below for wet and 160 acres and below for dry; (*b*) ayacut blocks between 50 to 100 acres of wet and 160 to 320 acres of dry; (*c*) ayacut blocks of more than 100 acres wet or 320 acres of dry.

The discharge in these channels (minor distributaries and field channels) is fixed as indicated here: (*a*) The discharge is calculated at 1 cusec for every 25 acres of wet or 80 acres of dry; (*b*) the discharges are calculated taking the above duties but limiting the maximum discharge to 2 cusecs.

The discharge in the minor distributaries shall be calculated at 50 acres wet and 160 acres dry for 1 cusec. But field channels should be designed at 25 acres wet and 80 acres dry for one cusec. The maximum discharge in any field channel shall be limited to the discharge in the minor distributary.

(*iv*) A level survey is conducted in the ayacut for (*a*) fixing up the alignment of the field channels; (*b*) to check up the commandability of each S. No.; (*c*) to fix up the position of drops by ascertaining

Typical scour in un-controlled minor distributaries.

Field metal dumped drop.

the general ground fall; (*d*) to fix up the alignment of the drainage for providing connection for the field channel to the vanka.

(v) To ensure these, the finalised ayacut plan has to be first obtained; and with this plan in hand a thorough reconnaissance of the entire ayacut area has to be made, marking out on the plan the approximate positions and course of the ridges and vankas and the position of the field channels as proposed. From the extents of the survey numbers noted on the ayacut plan, the required capacity of each of these field channels and its branches has to be worked out commencing from the tail-end.

(vi) As field channels are aligned to each survey number, it may be quite possible to see whether or not each individual survey number is commandable under that particular field channel. In case of doubt, spot levels of that particular field may be taken to examine the commandability. If any survey number or a part is observed to be uncommandable, it is reported for elimination from the ayacut.

(vii) In all cases where the commandability becomes difficult due to the field channels passing through dips etc., alternative aligments have to be tried on ground and marked on the plan, and may be checked up on the next day by taking levels.

(viii) As far as possible, the bends and other salient points of the field channels have to be verified with reference to the survey stones, so as to ensure the accuracy of the lay-out plan. The line of channels connecting the field channels to the vanka (drain) is to be fixed, selecting all those branches of the field channels which in themselves carry more than 2 cusecs capacity at head.

(ix) Levels are to be taken along the field channels down to $1\frac{1}{2}$ cusecs capacity. Levels have also to be touched at all salient places like vanka crossings, high mounds and other points noted during reconnaissance. With these levels and bed falls fixed previously, the positions of the drops may be fixed on these site surveys taking care to see that the commandability lower down is not affected. This means, the position of any drop will be just below an offtake.

(x) In the field channels, at all points where there is a change of slope, it is necessary to provide masonry structure or field metal drops. The point where the slope changes, may be taken as an obligatory point for providing a masonry structure and location of the other structures required may be fixed keeping this in view.

(xi) In most cases it may not be possible to give drops of more than 2 feet as otherwise either the command lower down will be affected or the channel will have to run in heavy embankment. Where the embankments are inevitable, as a general rule, they should not be more than 1 foot. Pucca drops of masonry core wall or concrete glacis type are to be provided only for field channels carrying more than $1\frac{1}{2}$ causecs.

(xii) Dumped field metal drops are to be provided for all channels carrying less than $1\frac{1}{2}$ causecs, every fourth drop in the channels carrying $\frac{1}{2}$ to $1\frac{1}{2}$ cusecs may be pukka masonry drop.

(xiii) The tail end shall invariably be provided with a masonry tail dam for all channels.

(xiv) To induce the ryot to utilise the water, and to speed up the development of the ayacut, it is necessary to keep the water flowing, in all the channels. If this water is not utilised on the fields, it will naturally find its way to the nearest drain by the shortest route. As the water thus flows from the ridge to the valley by the steepest ground slope, it will cause serious erosion and retrogression of levels. This has been avery serious problem to combat with during the first year of the development of the project. Some of the field channels have scoured to depths of 4′ to 5′ and widths 10′ to 20′ and meandered for considerable distance on either side. The retrogressions have travelled up-stream into the minor distributaries causing vary serious damage. It is therefore necessary to provide for a pucca masonry

tail dam at the end of each field channel and also to excavate a drainage course from this point to the nearest vanka and provide along this, good check-dams in field picked metal. This is absolutely necessary at least in the initial stages of the development of the project.

(xv) The work on field channels cannot be said to be complete without the drain connections given in a proper manner, with the masonry drops and tail dam constructed as per standards for the channels required to carry more than 1½ causecs discharge.

DESIGN OF THE DISTRIBUTARIES

All channels are designed to the following standards:

(i) For channels carrying more than 10 cusecs.

Bed width to depth ratio co-efficient of rugosity .. 3 to 4 0.025

Fall not steeper than 1/1320 and not flatter than 1/2640

Velocity to be between 0.9 and 1.1 times Kennedy's critical velocity .. $Vo—0.84\ D^{0.64}$

(ii) For channels carrying upto 10 cusecs:

	Slope not steeper than	Limiting Velocities
(a) 5 to 10 cusecs	1/1320	2'/Sec.
(b) 3 to 5 cusecs	1/990	2'/Sec.
(c) 1½ to 3 cusecs	1/660	1½'/Sec.
(d) ½ to 1½ cusecs	1/440	1'/Sec.
(e) upto ½ cusecs	1/220	1'/Sec.

Bed width to depth ratio: 3 to 4 co-efficient of rugosity—0.025.

The following bed widths may be generally adopted for all channels:

Discharge		Bedwidths
5 cusecs	..	4' 0"
4 cusecs	..	3' 6"
3 cusecs	..	3' 0"
2½ cusecs	..	2' 0"
2 Cusecs	..	2' 0"
1½ cusecs	..	1' 0"
1 cusec and less	..	1' 0"
For field channels only	..	1' 0" (Sides vertical) carrying less than 1 cusec.

MASONRY WORKS

Culverts

All roads and plan marked cart tracks are provided with culverts. And all culverts for roads are designed for I.R.C. class 'A' loading, the clear road widths between kerbs for all provincial and national highways being 32 feet, for district roads being 22 feet and for all other village roads being 12 feet. The maximum construction of waterway for these culverts is upto 50 p.c.

The culverts may be pipe culverts or with abutments and precast R.C. slabs or stone slabs. Paved ramps shall be provided as far as possible, particularly in black soils, but when inevitable they should be provided with a minimum width of 12' 0" and level approach of at least 15' 0". A slope of not steeper than 1 in 8 is necessary.

Cross drainage works

For the first portion of its length, and for some length after crossing the saddles, the channels run on contour and in this portion many drains—big and small—are to be crossed. The crossing is affected generally by providing masonry cross drainage works for all drains carrying maximum flood discharges of over 5 cusecs. Different types of structures are provided for different discharges.

The best type of crossing is a canal syphon as such a structure does not very much interfere with the drainage. Most of these drainage courses serve as cart tracks connecting the different villages or fields. Therefore to facilitate crossing by carts the width of the drainage waterway is kept as 12' as a minimum. To obviate the need for depressing the canal too much and risk silting up of the barrel, and to obviate necessity for forming approach embankments and risk leakages and breaches and consequent heavy outlay in repairs and maintenance, the alignment is taken such as to cross the drainage in a 2' cut at the deepest point.

The maximum flood discharge allowed for in these drains is calculated at 1 cusec per acre of catchment which is equal to 1" precipitation per hour.

The different types of structures adopted are barrel or pipe syphon. Wherever it becomes inevitable pipe aqueducts also are provided.

Drops

To negotiate the steep fall in the ground a large number of drops are necessary. The types of drops adopted are well-type, core-wall type and glacis type. Some glacis type of drops constructed with only rough stone, have collapsed by undermining of the apron at or just below the commencement of the glacis. Where masonry or concrete glacis drops are provided or rough stone drops are grouted with cement concrete, the structures are functioning satisfactorily. In the case of a few core-wall type of drops the core-wall is out-flanked by scouring on the sides and the drop obliterated. In all the cases of failure, want of provision against creep was the only cause. The length of creep that is necessary in these cases for the soils obtaining in this area is anything upto 1 in 5. It is very necessary to do the refilling of the foundations excavated for the core walls with very great care, as otherwise the actual hydraulic gradient would be very flat coming upto 1 in 10 or even 1 in 12. It is desirable to provide impervious revetments and aprons on the upstream side of the

4' - 0" core wall drop for major distributary.

drops and also provide revetments with panel walls on the down-stream side. These panel walls help in ensruing thorough and tight packing of the revetment, prevent easy dislodgment of the rough stone revetment and when the latter occurs it will be localised.

Different types of drops are provided for different discharges. For channels carrying less than 1½ causecs, mere dumping of field metal in the shape of a saddle is found to be sufficient. These drops are however only 1 ft. drops.

Sluices, dividing dams, and control points

For all off-takes from the major distributary or direct pipes from the main canal, sluices with paddle or needle shutters are provided. For offtakes for minor distributaries dividing dams are constructed.

The control point is a dividing dam when the common channel bifurcates into two branches feeding the dry blocks and wet blocks. This is to be provided with shutters and locking arrangements, to facilitate cutting off discharges in any branch when not required.

The following points are observed in connection with the lay-out and construction of these structures:

(i) All dividing dams and control points are to be constructed such that the included angle is 120 degrees.

(ii) Whenever possible they may be combined with a drop or at least 0.5 foot drops may be provided in all the control points and dividing dams for both the offtakes to avoid silting up of the same.

(iii) The sills of the notches in both branches should be at the same level.

(iv) The notch openings for the control points shall be to suit shutters of standard size of 1'-0", 1'-6" and 2'-0" width.

(v) Instead of masonry dividing dams pipes of suitable diameter may be fixed in earth for all offtakes of less than 1½ causecs. When the discharges in the two branches are nearly equal both the channels will be provided with pipes.

(vi) Irrespective of all other considerations, the sill level of all the pipe sluices of the major distributary should be at the bed level of the distributary, as otherwise, they do not draw water during low supplies particularly in the initial years.

EXECUTION OF WORK

As the localised ayacut is spread out in small bits throughout the commanded area, the length of the channels and the number of masonry works in them is very large. In an area where both skilled and unskilled labour is scarce it is really a difficult task to organise and execute this work.

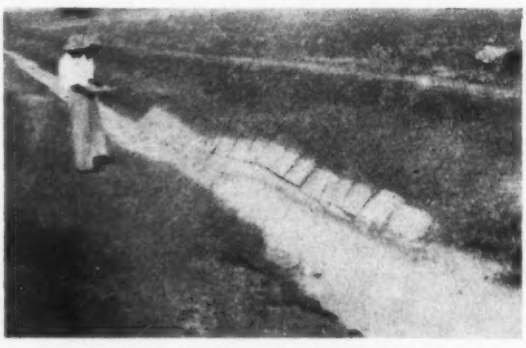
The area is divided into contiguous blocks each covering an extent of 10,000 acres and one Sub-division consisting of one Asst. Engineer and five Section Officers is kept in charge of each such block. If the staff are experienced, they should be able to complete the investigation, and execution of works for the entire area in a working season (non-rainy period) of about 6 to 7 months. Statements I and II give an idea of the standard out-turn that may be prescribed and magnitude and value of work involved in each block.

As the works in the distributary system are small and spread out over a vast area, no big contractors will normally come forward to take up the work. It is therefore to be done mostly departmentally by engaging petty piece workers for labour contract only.

For executing these works for a unit of 10,000 acres the labour force required for work during the season, is given in statement III.

DISTRIBUTION OF WATER

The main canal being 250 miles in length, it takes nearly seven to ten days for the water to reach the tail end after it is let down at head. As such it is not



Masonry glacis drop on minor distributary.

possible to effect the daily control of the discharges in the main canal. As regards the distributaries also the case is similar. Besides the length of channels, the steep fall in the ground and provision of the large number of drops makes it very difficult to effect daily control of water at head of the channel, therefore a number of escapes are provided along the main canal and major distributaries. The minor distributaries are connected to the drains at the tail end of the parent field channel. The actual distribution of water to the field is effected through the small field channels, water being drawn as and when required. For distribution of water in the small field channels and for controlling the discharges and duration of flow depending upon the demands, there are *Neerganties* appointed by the State. They work under the village officers.

CONCLUSION

The work on the distributary system of the T.B.P. Low level Canal is practically completed. The work in the Andhra area is however completed in all respects and water is made available for the full localised extent of 1,50,000 acres.

Inspite of construction of a large number of structures in view of the fact that the soil is mostly black cotton soil, and the countryside badly cut up, it is really a difficult problem to maintain the channels in an efficient condition. And to ensure continuous supply, great care and attention is required in the first few seasons until the channel section takes a set, and the ryots themselves are able to look after the maintenance and distribution.

For maintenance of these channels 10 lascars and 3 mistries are appointed at the rate of one set for every 10,000 acres block, and the cost of this maintenance establishment and petty repairs will come up to about Rs. 1/- per acre per annum.

STATEMENT I

Statement Showing Magnitude of Works

The length of channels and number of works per 10,000 acres of ayacut (one Sub-division unit for one working season)—for investigation and execution of works:

1. *Major Distributaries—*		
a. the length of channel for investigation (including alternative aligments)	10	miles.
b. Excavation of channels approximately 350 units per mile at Rs. 23/-	7½	,,
c. Masonry (works @ approximately Rs. 1,750/- each) (25 drops, 5 cross drainage works and 3 culverts).	33	Nos.
2. *Minor Distributaries:*		
a. Length of channel for investigation	40	miles.
b. Excavation of channels (approximately 100 units per mile at Rs. 20/- per unit)	36	,,
c. Masonary works (@ approximately Rs. 300/- each (200 Nos. of drops, 30 cross drainage works and 10 culverts).	240	Nos
3. *Field channels*		
a. Area to be investigated	10,000 acres (about 15 square miles)	
b. Excavating of channels, parent field channels (@ approximately 60 units per mile @ Rs. 17/- per unit).	22	Miles
Small field channels (@ approximately 6 units per mile @ Rs. 17/- per mile)	88	,,
c. Masonry works (@ approximately Rs. 150/- each) (375 drops, 20 cross drainage works and 5 culverts.)	400	Nos.

STATEMENT II

Statement showing costs of different items of Distributary System

Item-war cost per acre of ayacut

	Major	*Minor*	*Field channels*	*Total*
(*i*) A. Preliminary expenses	0 8 0	..	..	0 8 0
(*ii*) B. Land acquisition. Cost of land revenue establishment charges for acquisition	4 0 0	10 0 0	5 0 0	19 0 0
(*iii*) C. Works (All works drops, cross drainage works, and culverts)	6 0 0	7 0 0	6 4 0	19 4 0
(*iv*) K. Buildings. (Quarters for Supervisors and Laskers)	0 8 0	..	..	0 8 0
(*v*) L. Earthwork	6 0 0	7 0 0	3 0 0	16 0 0

STATEMENT II—*contd.*

(*vi*) O. Miscellaneous (Supplying and fixing demarcation stones and excavation of diversion drains, formation of inspection tracks etc.)	0	4	0	0	8	0	0	4	0	1	0	0
(*vii*) P. Maintenance: (Maintenance of completed reaches—before water is let in) ..	0	4	0	..			..			0	4	0
Total	17	8	0	24	8	0	14	8	0	56	8	0
Drainages	..			..			..			3	8	0
Grand total for Distributaries & Drainages ..							per acre			60	0	0

NOTE:—Expenditure under Sub Heads "A" and "K" covering all work for the three categories of channels viz. major, minor and field channels are all charged to major distributary only.

STATEMENT III

Quantities of work and Labour and Transport Required.

1. *Earth work excavation:*

(*a*) Major distributaries
7½ miles @ 350 units/mile — 2,625 units.

(*b*) Minor distributaries
36 miles @ 100 units — 3,600 „

(*c*) Field channels:
Parent field channels:
22 miles @ 60 units — 1,320 „

Small field channels
38 miles @ 6 units — 528 „

Total: 8,073 units.

or say 8,100 units (1000 cft.)

For completing this work in 6 months period the labour force that would be required is 750 mazdoors.

2. *Masonry works:*

(*a*) 33 major distributaries
@ 15 units/each — 495 units.

(*b*) 240 Minor distributaries
@ 4 units/each — 960 „

(*c*) 400 Field channels
@ 3 units/each. — 1,200 „

2,655 units

or say 2,700 units (100 cft).

For the above quantity of finished work the different items and materials required are:

Rubble	2000 units.
Broken stone	700 „
Sand	1000 „
Cement	800 tons
Steel	5 „

Hume pipes of different diameters 6″ to 30″: 150 Nos. of 8 ft. length.

With an average lead of 3 miles for stone, sand and broken stone, and about 40 miles for cement from railhead, this requires: two lorries for transport of cement and Hume pipes and 75 bullock carts for transport of stone, metal and sand. A hundred stone dressers and masons and 10 carpenters, fitters and others are also required for the job.

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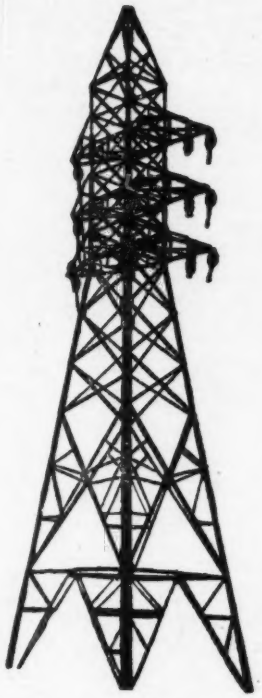

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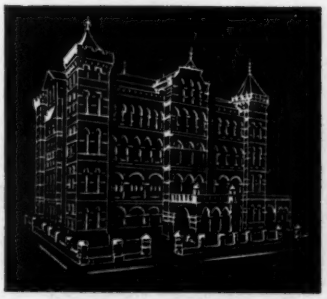

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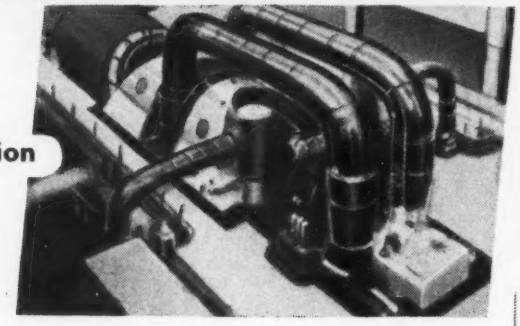

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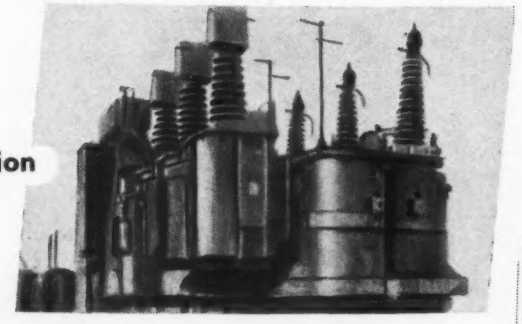
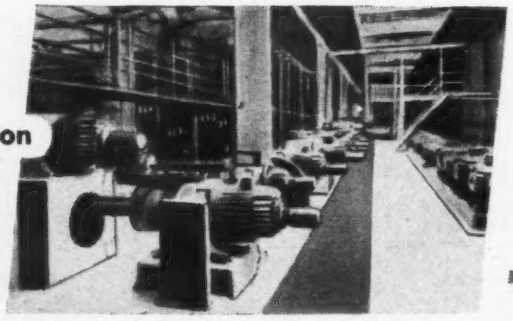


Distribution



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Power Position In Greater Mysore

by J. L. D'SA,
B.E., B.SC (HONS); A.M.I.E.E.;
Chief Engineer, Mysore Electricity Board

THE Industrial and the economic prosperity of the State of Mysore is due mostly to its outstanding physical features and geographical location. Situated in the southern part of the high Deccan Plateau it has a high rainfall incidence in the Western Ghat region. Mysore has a large number of rivers and tributaries to its credit, the Cauvery flowing towards the east and the Sharavati towards the west being the two most important. There are other equally good river valleys like those of the Tunga and Bhadra on the northern side, and the Shimsha and Arkavati on the southern side.

CAUVERY POWER SCHEME

Geologically too, Mysore is lucky. One of the richest gold mines of the world, lies within its territory in Kolar District. Messrs. John Taylor & Sons of England had secured the lease for gold mining in the Kolar Gold Fields and the mining operations were being carried on with the aid of steam power which naturally was expensive. Cheap hydro-power was the need of the hour. Prior to taking up gold mining in the State, the Western countries had made sufficient progress in the generation of hydro-electric power. With this as a guide the illustrious and benevolent rulers of Mysore, assisted by able administrators, realised the immense possibilities of harnessing the Cauvery river for purposes of power generation. The Cauvery Power Scheme was therefore launched in the year 1898 to generate at the famous falls of Sivasamudram, power for being utilised at Kolar Gold Fields. The administrators of the time were apprehensive of the success of the Mysore undertaking; but the foresight of Sir K. Seshadri Iyer and the zeal with which this scheme was taken up, went to prove that a distance of 92 miles could be traversed through a high-tension line for utilisation of power at Kolar Gold Fields. Incidentally, this was the longest high-tension transmission line in the world at the period.

Thus, nature's bounteous gifts to Mysore, the need for cheap hydro power for gold mining industry initially and other industries eventually and the earnest desire of the illustrious rulers and able administrators of the State to bring Mysore to the forefront, have contributed greatly in making Mysore a 'Model State'.

The Cauvery Power Scheme originally meant to help produce gold at economical rates at K. G. F. was later utilised to light up the larger cities of Mysore and Bangalore as also for the development of various other industries. Originally the scheme consisted of a small anicut to the Cuavery river at Sivasamudram, a canal leading the diverted waters to a forebay at the Bluff, and two steel penstocks conveying the water to two machines with a total installed capacity of 5130 kW. These were housed in a generating station in the gorge giving a gross head of 415 ft. As the demand for power increased additional generating units, transformers and the connected switchgear were added on from time to time to meet this growing demand, As time went the old and out-moded units were replaced with improved types and by the year 1938, Sivasamudram Power Station had a total installed capacity of 42,000 kW. Mysore had by this time become the foremost State in India and perhaps in the East, in the generation, transmission and distribution of hydro electric power.

As the demand for power in the State was growing by leaps and bounds, no time was lost in investigating and undertaking new schemes to provide for additional generating capacity. The scheme known as the Shimsha New Project was started in the year 1935 and completed by 1939. Two units of 8600 kW. each giving a total installed capacity of 17,200 kW. were installed at Shimsha in order to augment the generating capacity at Sivasamudram. The total in the State thus stood at 59,200 kW. installed. The Shimsha scheme utilises the waters of the same river Cauvery, through a canal 7 miles long from the Sivasamudram Balancing Reservoir. This canal is designed for an ultimate discharge capacity of 900 cusecs, though at present only 300 cusecs are being drawn for power generation. The peculiarity of this Shimsha Scheme is that the water conductor system from the Sivasamudram Balancing Reservoir to the forebay at Shimsha, is intercepted by two valleys, each of which is negotiated by inverted steel siphons, of 7 feet diameter.

The first one across the valley Handihalla is about 1600 ft. long while the other from 'F' point to forebay is about 2400 ft. Only one siphon has been installed at present in each of the two valleys and provision has been made for adding two more at a future date. The head obtaining at the Shimsha generating station is 639 ft. and on account of this greater head, it has been programmed to utilise eventually all the 900 cusecs of water from Sivasamudram so that 50 per cent more power could be generated.

MAHATMA GANDHI HYDRO-ELECTRIC STATION

Simultaneously with the undertaking of the Shimsha New Project, the harnessing of the waters of the river Sharavati in the north was also put on hand. This project named after the Father of the Nation, Mahatma Gandhi, generates power near the Jog Falls, a place of outstanding beauty which has attracted and enamoured tourists from all over India and abroad. With an installed capacity of 1,20,000 kW. the Mahatma Gandhi Hydro Electric Station is the largest hydro electric station in the State and one of the largest generating stations in India today.

This station has eight units, four of 12000 kW. each and four others of 18,000 kW. The maximum peak load recorded in this Station today is 1,10,000 kW. This scheme consists of a dam across the River Sharavati at Hirebhaskar for the impounding of 25,000 m.cft. of water, an anicut at Karagal lower down for diverting the water to the power canal which is of 1150 cusecs capacity. This canal passes through an R.C.C. duct 300 ft. long on to the 'Sirur' Balancing Reservoir of 8 million cft. capacity and then on to the forebay. Four steel penstocks, each 3300 ft. long approximately, having initial diameters of 6 ft. emerge from the forebay and these bifurcate lower down into 8 pipes of small diameter to feed the eight units.

Thus the Mysore Electricity System, from a humble start of 5.13 mW. installed capacity in the year 1902, has now to its credit 179.2 mW. of installed capacity with a system peak load of 141.2 mW. During this half a century or more the Government of Mysore have invested over Rs. 2,780 lakhs on the hydro electric development. The generation of electricity in k.W.h. has exceeded the 700 million mark, the annual gross revenue of the Department has been over 3.2 crores and the per capita consumption of electricity has reached 58 units, the highest among the Indian States, the All-India figure being only 13 units. The number of towns and villages electrified has exceeded 1000. Mysore has thus recorded a tremendous growth both industrially and economically and with this background, she has entered the field of intense development in the Second Five Year Plan.

During the First Five Year Plan almost all the programmed works—mostly rural electrification and lift irrigation schemes—were initiated and most of them were completed. Against a planned expenditure of Rs. 13.76 crores the actual outlay incurred, inspite of adverse conditions such as non-availability of essential materials, was 10.39 crores. Except for the completion of the Second Stage works of the Mahatma Gandhi Hydro Electric Scheme, no other new power project was undertaken by the Mysore Government during the First Five Year Plan.

The Tungabhadra Hydro Electric Scheme which is a joint venture of Mysore and Andhra Governments is under the control of the Tungabhadra Board. The scheme contemplates generation of 36,000 kW. at the Tungabhadra damsite and another 36,000 kW. at the canal power station at Hampi.

SHARAVATI VALLEY & BHADRA RESERVOIR PROJECTS

Two other schemes, namely, the Sharavati Valley Hydro Electric Scheme and the Bhadra Reservoir Hydro Electric Project were however investigated during the First Five Year Plan period for being taken up during the Second Five Year Plan period. The latter project consists of two generating stations at the foot of the Bhadra Dam now under construction near Lakkavalli, one at the left bank and the other at the right bank. The installed capacity of these two stations combined will be 41,000 kW. and power from this scheme is programmed to be made available from 1959-'60.

The Sharavati Valley Project is the mightiest of all schemes in South India. It contemplates the full utilisation of all the waters of that valley. The Sharavati river discharges annually an average of over 160,000 million cubic feet of water, of which only 36,500 million cubic feet or 23 per cent is now being utilised by the Mahatma Gandhi Hydro Electric Works. Investigations have revealed that a generating station could be located in the valley a couple of miles lower down the present station where a head of 1515 feet could be obtained. The scheme consists of:

(*a*) A dam across the River Sharavati at Linganmakki to impound 1,56,400 m.cft. of water.

(*b*) A power canal with a capacity of 4500 cusecs continuous discharge

(*c*) Two tunnels, one with free board 5 furlongs long and the second of the pressure type 4 furlongs long.

(*d*) A pick-up dam at Talakalale.

(*e*) A forebay, penstocks and a generating station. It is estimated that about 7,10,000 kW. of power could be generated at this station at 60 per cent load factor. The size and number of units are being finalised.

This reservoir will also supply water to the present Mahatma Gandhi Hydro Electric Station at Jog. The ultimate installed capacity of this valley therefore will be 8,30,000 kW. It is proposed to transmit huge blocks of power from these two stations to Shimoga and on to Bangalore, over 220 kV. transmission lines. The first stage of the scheme as approved by the Planning Commission for being undertaken during the Second Five Year Plan period provides for the installation of two generating units of 71,000 kW. each. The work on the project is actively taken up.

Besides the above two major power generation projects, various other power transmission and utilisation schemes, such as construction of high tension transmission lines, installation of unit substations, rural electrification etc., are also planned to be executed during the Second Five Year Plan period and the total amount approved of by the Planning Commission for all these works is of the order of 23.37 crores.

With the completion of the works contemplated in the Second Five Year Plan, the electricity system in the former Mysore State will have assumed a large magnitude. It will have 2,27,200 kW. as installed capacity, generating 1400 million units of power and earning a gross revenue of Rs. 600 lakhs per annum.

After the States reorganisation on the 1st November, 1956, Mysore is enlarged to more than double its former size. The Electricity Department has to cater power to an additional region of 41,033 square miles with a population of 95.5 lakhs of people. Including the figures of the present Mysore State, the total extent of the Greater Mysore would be 74,332 square miles and the total population to whom the benefits of electricity have to be extended would be 194 lakhs. The responsibilities of the Electricity Department, Government of Mysore are great in the new set up. The task is stupendous inasmuch as the integrated areas are very poorly developed as far as electricity is concerned.

From a study of the areas now integrated it is seen that for an integrated area of 41,033 sq. miles the power availability is only 5660 kW. as against an installed capacity of 1,79,200 kW. for an area of 33,289 sq. miles of former Mysore State.

The integrated regions are already being served by the existing electricity system of Mysore. The Hubli and Dharwar area is being fed from Jog, Tungabhadra Dam and Hyderabad South regions from Davangere via Hospet, Kollegal from Sivasamudram and South Canara from Shimoga.

With the merging of the Raichur District with Mysore, the left bank of the Tungabhadra Dam at Munirabad with its hydro electric scheme comes over to Mysore. This station will have initially, an installed capacity of 27,000 kW. comprising of three generating units of 9,000 kW. each. This station is likely to go into commission by the year 1960-61.

Thus by the end of the Second Five Year Plan, Greater Mysore will have a block of 4,00,000 kW. of power available to enable it to cater to the fast growing power demands of Greater Mysore. The Electricity Department has plans to make available this huge block of power to every nook and corner of the new State, recently formed.

This is not all. The natural resources of Greater Mysore are enormous. In hydro power a rapid survey has indicated a potential of 3 million kW. of which only 13 per cent will have been harnessed by 1962. The future is hopeful, and engineers as never before will have to contribute their maximum to enable this great State to become a model to the rest of India.

(Continued from page 36)

EVOLUTION OF ADMINISTRATION OF THE TUNGABHADRA PROJECT

circles which are attending to works relating to the Tungabhadra left bank canal namely the Reservoir construction Circle and the Raichur Circle. The former has six divisions under it and the latter two divisions besides other divisions unconnected with this Project.

The Hydro Electric Work on the left bank canal also came under the control of the Chief Engineer for Electricity, Mysore. From 1.10.1957, the Mysore Electricity Board was formed. The Government of Mysore appointed another Chief Engineer called the Chief Engineer, Hydro Electric Construction Projects so that all the Hydro Electric Projects in the State are completed expeditiously. The power house at Munirabad is being constructed under his direction and control. A circle has been formed for this purpose under a Superintending Engineer. There are all together three divisions working under him.

The common portion of the works relating to the Governments of Mysore and Andhra Pradesh are being executed and maintained by the Tungabhadra Board and other works lying in the respective territories of the participating Governments and meant for their use exclusively are being looked after by them directly.

Evolution of Administration of the Tungabhadra Project

by G. N. PATHAK, I.A.A.S.
Secretary, Tungabhadra Board

THE river Tungabhadra is a tributory to the Krishna, the second largest river in South India. It originates in the Western ghats in Mysore State and runs for about 400 miles before joining the Krishna at Sangamaheswaram in Andhra Pradesh. Prior to the re-organization of the States, it used to flow through four States Viz., Mysore, Bombay, Hyderabad and Madras. It used to form boundry between the States of Bombay and Mysore for a stretch of 35 miles, between the States of Madras and Bombay for 62 miles and between the States of Madras and Hyderabad for 192 miles. It was, therefore necessary that agreements should be reached between these States for the abstraction of waters of the Tungabhadra.

It was Sir Arthur Cotton "The irrigation wizard of South" who thought of harnessing the waters of the Tungabhadra for the benefit of the people of Rayalaseema who had been suffering from the curse of famine. Though the scheme was conceived as early as 1860, it could not be taken up for execution before the later part of the first half of the twentieth century. Negotiations had to be conducted by these Governments at various levels for determining the quantity of water to be utilised by them. An agreement was reached in the month of June 1944 between the Governments of Madras and Hyderabad. Another similar agreement was reached between the Governments of Madras and Mysore in the month of July, 1944. After these agreements were reached, the scheme was inaugurated on the 28th February, 1945 by the Prince of Berar on the Hyderabad side and by Sir Arthur Hope, Governor of Madras on the Madras side. After the inauguration ceremony, the question arose as to what would be the mode of agency for the execution of the project. The Hyderabad officers' opinion in this respect was that there should be a Committee of Control consisting of Chief Engineers of Madras and Hyderabad and a non-official retired Chief Engineer and the Members (Finance, Revenue and Public Works Departments) of the Government of Madras and Hyderabad. Their further opinion was that the Superintending Engineer would be either a Madras or Hydérabad officer, that Audit Officer would be an officer of the Deputy Accountant General's grade drawn from Madras or Hyderabad and that the Chief Revenue and Land Acquisition Officer would be an officer of the collector's grade of either Government. The question was again considered by the two Governments after the foundation stone was laid. The Government of Hyderabad held the view that the entire work should be under the control of a Superintending Engineer drawn from the Government of Hyderabad who would work directly under the Chief Engineer Madras. As the work was of joint nature, it was suggested by them that the Chief Engineer, Hyderabad should be kept informed of all orders and communications and that whenever he differed from the chief Engineer, Madras, he would ask for a Board meeting whose decision would be final. The Government of Madras were of the view that the services of a Superintending Engineer should be obtained from the Government of India on loan to be in charge of the construction. The suggestion made by the Government of Madras was not accepted by the Government of Hyderabad. The only course open was that there should be two Superintending Engineers (one from Madras and the other from Hyderabad) in charge of the work and to entrust to each some section of the dam and let each work under the direct control of his own Chief Engineer, co-ordination being affected by the Board of Chief Engineers. It was also decided that in addition to the co-ordination affected by the Board of Chief Engineers, the two Chief Engineers should meet and consult each other and act in co-ordination to the fullest extent possible so that the construction work proceeds unhampered.

Thus the Headworks were executed by two different agencies. The right half of the Dam was constructed by the Government of Madras whereas the left half by the Government of Hyderabad. The two canals i.e. right bank canal and the left bank canal were executed by the Governments of Madras and Hyderabad in whose territory they lay.

FROM FEBRUARY 1945 TO SEPTEMBER 1953

Right Side

The Project opened with the creation of a Special Circle called the Tungabhadra Project Circle with head-quarters at Madras under a Superintending

Engineer. The Circle was formed on 18.1.1945 i.e., about 40 days prior to the inauguration of this scheme. A division for the construction of the headworks and canal in the upper reach was created later in February 1945 with headquarters at Hospet. Another division was opened at Adoni on 25.5.1945. A third division for the construction of acqueduct across the Hagari was formed soon after with headquarters at Bellary. The headquarters of the Circle was shifted by the end of May to Bellary and started functioning at Bellary from 1.6.1945. This was known as Tungabhadra Project Circle, Bellary. One more Division was created later with headquarters at Bellary viz., Bellary Canals Division. A separate division for the Canal in the Headworks reach called the Hospet Canals Division was formed in the very early stage itself. A separate division was formed at Bellary called the Localisation Division to be in charge of localisation work under the entire low Level Canal in 1949.

For Headworks, one division was formed initially known as Headworks Division split up later on into two viz., Construction Division No. 1 and Workshops and Machinery Division and later on, one more division was formed viz., Construction Division No. 2. A separate Superintending Engineer was in charge of Headworks for which a Circle was formed in April, 1946 known as Tungabhadra Project Headworks Circle with headquarters at Hospet. All the divisions had the benefit of the facilities provided for the use of machinery and equipment for which a separate division viz., Workshops and Machinery division as mentioned above was formed from the very early stage. The whole mechanical set up was placed in charge of one Superintending Engineer who had joint responsibility of this Project and the Ramapadasagar Investigation works. The Circle office meant for the Mechanical Division was abolished with effect from 1.11.1952 when its necessity was no longer felt. When the works in the water spread area were taken up, a Special Road Division was formed on 19.12.1950. The whole set up was under the Chief Engineer, Irrigation, Madras who had besides the Tungabhadra Project other duties to perform.

Left Side

As agreed to by the Governments of Hyderabad and Madras, the works relating to the Dam proper were divided into two halves and placed under the control of a Superintending Engineer drawn from the respective States. Accordingly, a Circle known as the Reservoir Circle was formed in the later half of 1945. The Superintending Engineer was in charge of the headworks. This Circle had under its control three divisions namely Reservoir Construction Division, Materials Division and Mechanical and Stores Division with necessary workshop facilities. So far as the Canal works are concerned a separate Circle known as the Tungabhadra Canal Circle with Headquarters at Yermaras was formed. For the execution of this canal, six divisions were working under this Circle—five for canal construction and the sixth known as Mechanical Division.

FROM THE 1ST OF OCTOBER 1953

Right Side

With the formation of Andhra State on the 1st October, 1953 and the transfer of the seven taluks of the Bellary District to Mysore, the administrative set up underwent certain changes. The headworks and the canal upto 75th mile fell in Mysore while the balance in Andhra State. In pursuance of subsection (4) of Section 66 of the Andhra State Act, 1953, the President of India established a Board by the name of Tungabhadra Board consisting of a Chairman appointed by the Government of India and six members. The Board was vested with powers to deal with all matters relating to works or connected with the Tungabhadra Project which were common to both the States of Andhra and Mysore. Unfortunately however the Board could only function at the level of a Chief Engineer as its powers were restricted to those of a Head of Department and all matters not covered by the delegation of powers had to be referred to the Government of India for their orders.

The Chairman of the Central Water and Power Commission was appointed as the Chairman of the Board, in addition to all his other multifarious duties. The headworks were situated at a distance of one thousand miles from his headquarters. The members were also part time members with headquarters at various places being in fact the Chief Engineer, Irrigation and Electricity of the participating State Governments. In the circumstances the Board set up two sub-committees viz., the Irrigation Sub-committee and the Electricity Sub-committee to advice it on matters relating to irrigation and electricity. This Board functioned for about 18 months from the 1st October, 1953 to 15th March 1955. It was however felt that the constitution and functions of the Board needed revision in order to speed up the work and obviate delays in taking quick decisions. The report of the States Reorganisation Committee at page 95 observed that "It has been represented to us that after the creation of the Andhra State, the Tungabhadra Project Board, which was set up in terms of Section 66 of the Andhra State Act, could not function satisfactorily. The complaints were so serious at one stage that it was considered desirable to reconstitute the Board".

The Board was accordingly reconstituted by the Government of India, Ministry of Irrigation and Power in their Notification No. DW-VI4 (9) dated the 10th March, 1955. This Board consisted of a Chairman appointed by the Government of India and 4 members representing each of the Govern-

ments of India, Andhra, Mysore and Hyderabad. Subsequently the Hyderabad representative dropped out on the 1st November, 1956 and the Board now consists of a Chairman and three members each representing the Government of India, Andhra Pradesh and Mysore respectively. This Board has been virtually vested with the powers of a State Government in so far as the Project was concerned.

Even after the reconstitution of the Board, the then Superintending Engineer, Irrigation was promoted as Chief Engineer by his parent Government. As he had been associated with the Project from the very beginning, the Board retained him as their Chief Engineer-cum-Secretary. Two Deputy Secretaries—one dealing with administration and the other with Finance were appointed to assist him. Later on when the Civil works came almost to a close, the post of whole time Chief Engineer was abolished with effect from 1.11.1957. Posts of the two Deputy Secretaries were also abolished with effect from the same date. One of the Deputy Secretaries was promoted as Secretary who is continuing to hold that post since then.

From March, 1955 to November, 1958, the Board has met 21 times that is on an average a meeting has been held once in 10 weeks. For dealing with emergent and day-to-day works, the Board has given full discretion to the Chairman to deal with all such cases. Final orders passed by the Chairman are, however, placed before the next meeting of the Board for confirmation.

The functions of the Board include:—

(*a*) the completion of the construction of sanctioned Tungabhadra Project;
(*b*) the regulation of surplus water and power in accordance with such rules as may be made in this behalf by the Board;
(*c*) maintenance of the main canal and all other works common to both the States of Andhra Pradesh and Mysore;
(*d*) maintenance of the dam and reservoir of the Project;
(*e*) granting of leases of fisheries in the reservoir and in the Main Canal;
(*f*) proper utilisation of land acquired for purposes of the Project;
(*g*) any other functions incidental to or connected with, the functions specified in clause (*a*) to (*f*)

On the appointment of a whole time Chief Engineer the Irrigation Sub-Committee mentioned in paragraph 7 was abolished. The Electricity Sub Committee continued to function till the 1st October, 1957 when it was also abolished. The Chief Engineer, Major Irrigation, North Mysore was appointed as the Chief Engineer, Irrigation of the Board in addition to his duties under the Government of Mysore. Similarly, the Chief Engineer for Electricity, Andhra Pradesh was appointed as the Chief Engineer, Hydro Electric Scheme of the Board in addition to his duties under the Government of Andhra Pradesh.

With the formation of the Board, the two Circles under the Irrigation side of the Project were amalgamated into one Circle with Headquarters at Tungabhadra Dam. This circle has four divisions under its control namely Workshops and Machinery Division, Civil Division, Main Canal Upper Division and Main Canal Lower Division. The two Canal divisions were amalgamated on the 1st July, 1956 and this Division was finally merged with Civil Division on the 1st of January 1957. Consequent upon the promotion of the then Superintending Engineer, the Circle office was upgraded to that of the Chief Engineer with effect from the 17th of April 1955. This office was down graded to that of a circle office with effect from the 1st November, 1957 when the post of the Chief Engineer was abolished.

Another circle called the Tungabhadra Hydro Electric Scheme was also formed for executing the works relating to the Hydro Electric Scheme. In the beginning there were four divisions under this Scheme. At present only two Divisions meant for the Operation of the two Power Houses are functioning.

As the canal had been dug up to 173/3 mile till the 30th of September, 1953, the Government of Andhra Pradesh continued Adoni Division. The Localisation Division at Bellary was closed on the 23rd of September, 1953 and was re-opened at Yemmignur on the 24th September, 1953. The divisions continued functioning till the 30th September, 1958 and after that only Adoni Division is continuing.

The Board was entrusted with the common portion of work. So the Government of Mysore were left over with works relating to major and minor distributaries catering to the needs of the ryots of the Bellary District. One Division known the Special Irrigation Division was formed at Bellary on the 1st October, 1953 which is still continuing.

Left Side

As major portion of the construction of the dam was over by the middle of 1953, the Reservoir Circle was entrusted with the construction of canal works in 1956. Just before the reorganisation of the States, the entire project on the left side was under the charge of a Superintending Engineer with Headquarters at Munirabad. Consequent upon the reorganisation of the States, Raichur District which derives benefit from the Tungabhadra left bank canal came under the Mysore State. The Government of Mysore posted a Chief Engineer called the Chief Engineer, Major Irrigation (North) with headquarters at Munirabad. He was placed in charge of the Tungabhadra Project (left side) and other major projects in north Mysore. At present there are two

(Continued on page 33)

Tungabhadra High Level Canal

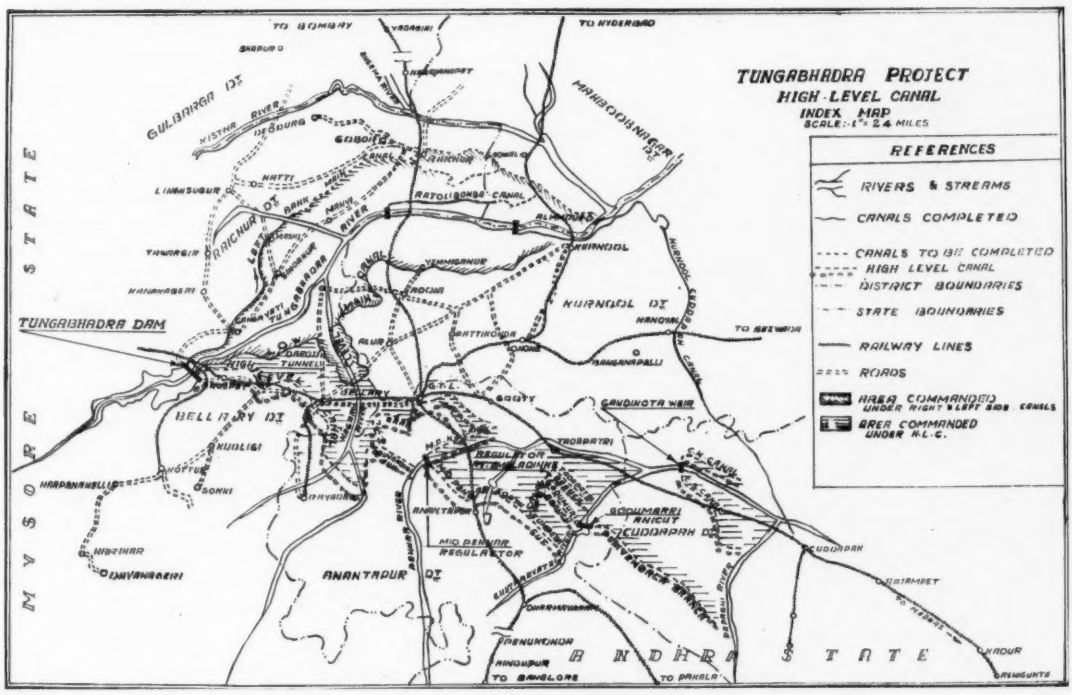
by L. C. MUNISWAMY REDDY, B,A.,B.E.
Chief Engineer, Irrigation Branch,
Tungabhadra Board

TUNGABHADRA Reservoir now in Mysore State was constructed to store the waters of river Tungabhadra to irrigate the large arid zones of the districts of Raichur, Bellary, Anantapur, Cuddapah and Kurnool on either sides of the river. Horrors of the famines in those districts are recorded and many persons and cattle have died for want of even drinking water prior to 1948.

The designers of the dam contemplated a system of tapping the reservoir at different levels so that during rainy seasons the surplus water could be diverted for about 5 months to a vast area of waterless tracts and give relief to the villages and their cattle. The M.W.L. of reservoir is at 1633 and sluices have been fixed to tap the High Level Canal at RL 1585, both on the right and the left banks. Power and irrigation sluices at 1550 are already functioning irrigating mixed crops to an extent of 5.8 lakh acres on left and 2.5 lakh acres on right side.

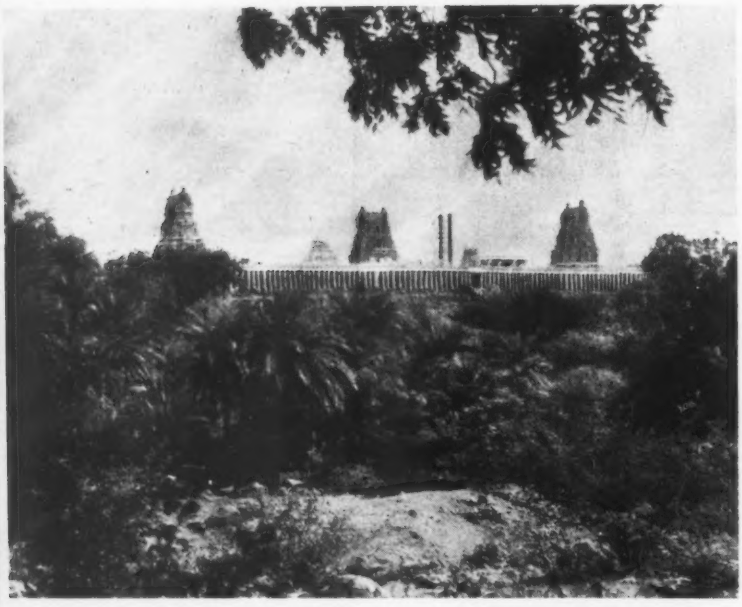
The High Level Canal is designed to utilise about 50 T. M. cft of water from the reservoir between 1633 and 1585 levels. The Index map will show that the High Level Canal flows hugging south of Bellary town (in its 60th mile) and crossing the two Hagari rivers, drops into the Pennar river. A branch canal runs beyond Guntakal town. A deep water shed cutting of nearly 74 feet depth near Uruvakonda enables the water being dropped to Pennar river. A regulator at Pamadi diverts the water to be taken along canals to most of the arid zones of Anantapur and Kurnool districts. The South Channel drops into the Chitravati river, thereafter enters Cuddapah district and is again picked up by Godumarri Anicut. This feeds the lands with 2 canals on either side of the river.

The canal has a bed width of 65′-0″ feet at the commencement and carries 4000 cusecs. It is pro-



Tungabhadra Project High Level Canal Index Map.

A view of the Pennar Regulator site from the Right Bank of the River.



A view of Penna Ahobilam Vanka with temple location

posed to irrigate about 4 lakhs of acres, dry and wet together. This canal assures drinking water and food to the villagers and their cattle in the gross commanded ayacut of 13½ lakhs of acres. Most of the ayacut is rich black cotton soil not requiring much water. It is estimated to increase the yield in the area by about 2 lakhs of tons consisting of jola, ragi, wheat, groundnut and paddy.

The salient features of the canal are:

Water is fed to the canal directly from the reservoir at RL Plus 1585 by a battery of 10 regulated sluices of size 12′×6′. The canal is proposed to be lined with cement concrete to minimise seepage and losses and this also minimises the section.

The bed width of the canal at the start is 65′-0″ feet with a side slope of 1½ : 1 and the depth of flow is 12′-0″ feet with a carrying capacity of 4000 cusecs.

It crosses the railway lines of Hospet-Kottur and Hospet-Guntakal in suitable ducts. In the first 25 miles, it hugs mostly the steep slopes of hills and passes through a lined R.C.C. tunnel 2510 feet long with a cross section of 534 sq. feet. It is only beyond this point that benefits of direct irrigation accrue to lands below, on its 31st mile.

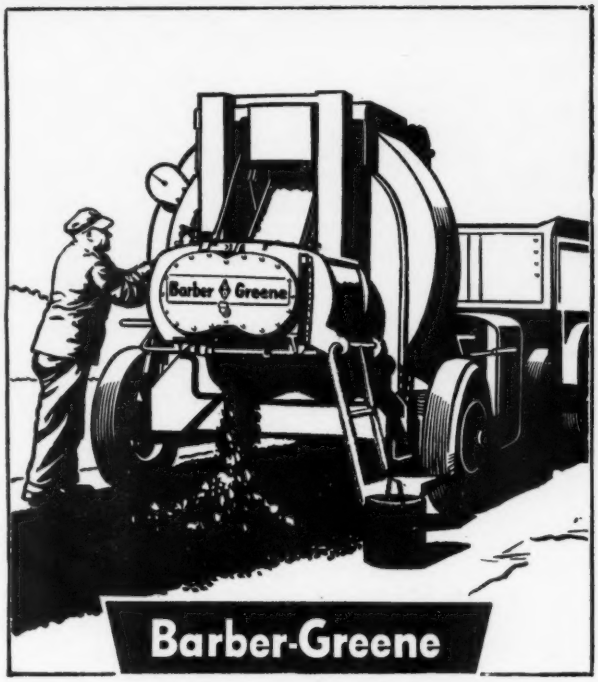
It syphons across the Narihalla river by a masonry and R. C. C. duct, to drain about 50,000 cusecs. The cost of this masonry work is estimated to be Rs. 9.6 lakhs. Next the canal crosses the Chinna Hagari and Pedda Hagari rivers by means of aqueducts which are estimated to cost 34 and 52 lakhs of rupees respectively. The Chinna Hagari Aqueduct is 1010 feet long (masonry portion) and is a R. C. C. trough of 3 compartments of 12′-0″ wide and 12′-0″ deep designed to carry 3000 cusecs.

The Pedda Hagari Aqueduct is 1712 long (masonry portion) and is a R. C. C. trough of 3 compartments 12′×12′ designed to carry 3000 cusecs.

On its 34th mile it will be an engineering feat to excavate a rock cut channel to carry 4000 cusecs near the water spread of Daroji Tank wherein a railway line hugs the slope of a steep rocky hill. The railway line is just above the water spread of the major Daroji Tank and this canal will have to be taken for nearly 3 furlongs between the railway line and the steep hill slope.

On its 116th mile the Main Canal crosses the water shed line between Hagari and Pennar rivers in a deep cut 45 furlongs long and a maximum cutting of about 74 feet and falls into the Pennar river which is about 90 feet lower.

The canal will feed in Mysore State 1,36,500 acres and in Andhra Pradesh 2,43,500 acres. The total cost of the scheme is estimated to be 22 crores of rupees.



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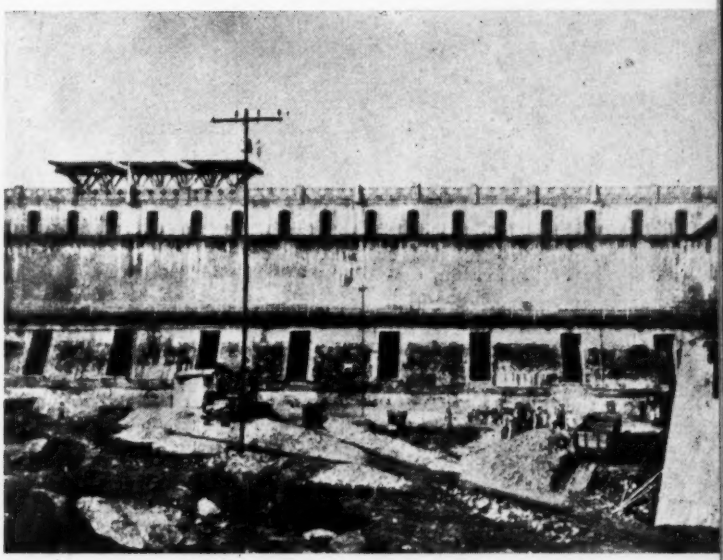
A view of Penna Ahobilam Vanka Infall to Pennar River



A view of High Level Canal vents in Tungabhadra Dam

Behaviour of Canal Banks in Low Level Canal During the Initial Stages

by P. VENKATARAMANA BHAT, B.E.,
Executive Engineer, Main Canal, Upper Division

WATER was first let down into the Power Canal on 1.7.1953, and thence to the Low Level Canal on 4.7.1953. This event was an occasion for great jubilation and self satisfaction for all concerned as it was the culmination of their efforts to harness and canalise the waters of the mighty Tungabhadra for the benefit of humanity.

At the same time when following the flow of water during its first run in the canal some fear and anxiety was lurking in the minds of some of us as to how the banks would behave at the sites of heavy embankments and cross drainage works and also whether the bed levels as excavated were correct. It was a matter for satisfaction for us that all the bigger embankments and the cross drainage works stood the test very well. The levels also proved to be correct and the water flowed as designed.

MISHAPS DURING TRIAL RUN

But it was found to our dismay that the smaller embankments, where the soil was silty black cotton clay and where special precaution had not been taken, were yielding during the initial run.

The first mishap occured at mile 3-0-0 of Low Level Canal on the second day of the trial run on 5.7.1953 when leakage was observed on both the banks just on the down-stream side connections of a type II R. C. Box-type under tunnel. This developed into a piping and tunnels about 3′ diameter were formed in both the banks before the flow was stopped. The canal was closed, banks reformed and strengthened and water was again allowed on 21.7.1953. On 22.7.1953, after about 18 hours of flow, piping started in the left bank at mile 7-5-0 (when the depth of flow was only about 1 feet above bed level and depth over ground about 5 feet.) The piping appeared at the rear toe and was controlled. But, as a tunnel about 9″ diameter was formed inside the bank, the bank was cut open, reformed and strengthened by constructing revetment in front and berms in rear. Heavy seepages were also noticed at embankment sites at miles 21/7, 22/7, 37/2-3 etc. All these and other similar vulnerable sites lower down were strenghened by bed filling during the period 22.7.53 to 10.9.1953.

Water was again let down on 10.9.1953 after completing these works and the discharge was increased gradually, from 25 to 200 cusecs. It reached the cross bund at mile 38/0 on 28.9.1953. When it headed up to about 6 feet above bed, piping started on the same day in about half a dozen places between 36-6-50 and 36-6-200 in the right bank. This developed into a breach within a few hours and supply below regulator at 17th mile was again stopped on 29.7.53.

Due to heavy rains on 3.10.1953 and 4.10.1953, all the drainages on the right side of the canal from mile 71/0 to 72/2 were in floods and breached the right bank at several places and entered the canal. The canal breached in the left bank at 74-7-400 on 5.10.1953 at night time when water headed up in the canal to about 7 feet above ground level or 1 feet above bed. This reach of canal from 74-4-0 to 75-1-0 upstream of Hagari aqueduct was therefore considered vulnerable and strengthened by bed filling and constructing revetments for front slopes.

Water was again let down below Narihalla regulator at mile 16-7-147 on 6.2.1954 and headed up at the regulator at 73-2-552 upto 2.5.1954, and was let down below the last regulator after completing the above works on 2.5.1954 for trial run. About 350 cusecs were let down. Subsequently the canal was closed for carrying out closure works on 15.5.54 and supply resumed on 3.7.54.

Thus in the first season of trial run from 1.7.1953 to 15.5.1954, there were two breaches and also two major pipings. There were 4 other minor pipings also which were closed by slipping earth in front.

In the second season, water was let down on 3.7.1954 and discharge was increased gradually. It reached the regulators at Narihalla (17th mile) and Dasapuram (43rd mile) on 7.7.1954 and 12.7.1954 respectively. The average speed with which the water was allowed in the canal was about 5 to 6 miles per day during the trial run. Later on the discharge was increased and a speed of about 12 miles per day was attained when water was let down after the last closure.

But the flow had to be interrupted during the period 18.7.1954 to 1.8.1954 below the regulator at Narihalla as a breach occured on 17.7.1954 in the right bank at 38-6-175 and also a major piping on 19.7.1954 in the right bank at mile 74-3-300 and two small pipings at miles 34-4-0 and 36-6-70 left bank on 17.7.1954 and 18.7.1954 respectively. The above breach was closed, other sites strengthened and supply was resumed again on 2.8.1954 below Narihalla regulator.

Thereafter, again upto 15.4.1955 there were 4 breaches (at 52-2-0 on 30.10.54, at 30-1-0 on 3.1.55, at 74-3-250 on 4.1.55 and at 38-5-450 on 27.2.1955), 8 major pipings and 18 minor pipings mainly in the reaches 74-3-0 to 74-4-0 and 36-0 to 39-0. But these were promptly closed and sites strengthened at these places without interrupting the flow. Though flow was reduced for about a week at the most when breaches occurred it was not stopped at any time. The canal was closed for carrying out closure works from 16.4.1955 to 15.5.1955. The supply was again resumed in the third season on 15.5.1955 and is flowing without interruption.

Thus, from the commencement up to July, 1955 there were 7 breaches, 12 major pipings and 24 minor pipings in the canal from head to mile 75/0.

Besides the above breaches and pipings there were very heavy seepages at several embankment sites, at sites of under-tunnels and even in partial cuttings. All these sites were strengthened by various methods during 1953, 54 and 55 and these measures have been very effective.

Before the causes of these pipings and the remedial measures undertaken are discussed it is not out of place to describe the trials and tribulations which we were subjected to during this period. When the breaches and pipings occurred our reputation as engineers was at stake. The public as well as some engineers did not hesitate to attribute these mishaps to bad workmanship or inefficiency of the engineers in charge of designs and construction, as many did not know that such breaches are not uncommon in any newly constructed canal during the initial stages. The stoppage or reduction in supply for closing these breaches or pipings was taken as a plea for the nondevelopment of the ayacut though really most of the ryots were not prepared for using the water for cultivation. The engineers were taken to task for failure to give an assured supply. The situation was really baffling at one time when pipings and breaches were occurring and their exact causes were not known.

Though we attributed some of the pipings and breaches to rats and crabs and we actually saw these rats inside the banks at some of the piping sites we were not quite satisfied with these reasons ourselves and for sometime we were labouring under a guilty conscience whether these mishaps might be really due to bad workmanship. We were under the perpetual fear and nightmare of getting an urgent message of pipings at any time. We had to run to the sites at night time and organise measures to control the pipings or breaches. We had no peace of mind or rest during this period till all the weak sites were strengthened. Moreover the staff who had to attend to these were quite new and different from these who actually executed the works as many of the Divisions were closed after the physical completion of the works. In addition to our regular work we were subjected to a drive to clear the accounts arrears and bills left over by the abolished Divisions.

In spite of these heavy odds all the staff worked patiently and played their part well. It was only after experience that we found that these pipings are occurring only in certain reaches due to peculiar soil and ground conditions. We have diagnosed the causes and have evolved measures to deal with them successfully.

Most of the weak spots have since been strengthened and an assured and continuous supply is now being given. Serious mishaps are not likely to happen hereafter and even if anything happens a technique has now been evolved for closing these breaches or pipings quickly and efficiently and the public now have confidence in the engineer's ability and capacity to close the breaches quickly without detriment to supply required for their crops.

CAUSES OF BREACHES AND PIPINGS

The causes of pipings are different at different sites. The following conditions however exist at almost all the sites where breaches or pipings have occurred. (1) The banks are either in full embankment mostly or in one to two feet cuttings at a few sites; (2) The soil with which the banks are formed is silty clay got from the adjacent borrow pits; (3) The soils contain calcium and sodium salts in varying percentages upto about 1%; (4) The pipings are caused due to percolation through the bund or under the foundation.

How The Piping Starts

The piping may start in one or a combination of the following way :—

(a) *By initial settlement:*—When the water in the canal seaks the newly formed bank and wets it initially, the portion wetted settles down leaving cleavage planes between the wet and dry portions of the banks. Water percolates freely in these pores and cleavage planes and where these pores are continuous and large the percolating water may move even the soil particles creating a run or tunnel. When this tunnel is once formed it

develops rapidly. These tunnels may get blocked up automatically by top earth slipping down or may form large cavities into which the top earth may or may not slip down in time and may establish a passage for water to flow freely through the bank resulting in piping. As the line of percolation always dips down to the rear toe the exit of the pipe is at the rear toe or a little above the toe. The ingress may be at the front water level or even below depending upon the level at which the shrinkage crack is formed in the front.

The ingress and egress may be through several small tunnels at the commencement and may appear at several points at the commencement. But, when the piping in the region develops these join each other and form into single large tunnel, the smaller tunnels getting either blocked up automatically or merged with the larger tunnel. The direction of these tunnels is zig zag both in elevation and plan. This tunnel develops into a breach if not controlled in time by blocking it in front or raising the level of its exit by blocking it continuously from rear also till its level is raised thus reducing the velocity of flow in stages. Most of the pipings and breaches that have occurred are due to initial settlement.

(b) *Through rat or insect holes*:—Pipings also start by water percolating through insect or rat holes existing in the bank where the soil is also silty clay. Even if the holes exist for a portion of the section of the bank a connection may be established by percolation through initial shrinkage cracks and the piping may start. The presence of the rats with their new born young ones were found when examining the tunnel caused due to piping at mile 36/6 of Low Level Canal on 29.8.1954.

(c) *Through highly saline soils*:—The salts in dry soil when they come in contact with water increase in volume due to hydration to almost double their volume. When changes in temperature or humidity occurs, the salts present in a compact layer of soil change in volume and break up the structure of the soil crust. The soil grains once pushed out of position on hydration of the salt are unable to fall back into their original position when dehydration takes place. The loose and fluffy condition of the soil is thus brought about. This loose soil absorbs water quickly especially when the soil contains excess of silt and helps the soil to attain quicksand condition and create weak cavities in banks through which piping may start. This condition exists in the soils at 36/0 to 39/0, 74/0 to 75/1 and 52/2.

(d) *Excess of silt in the soils used for embankment*:—This is one of the chief causes which has helped free absorption and agressive percolation leading to piping. The analysis of some of the soils used for embankment has shown excess of silt as well as presence of salts in the soils as below:

Location of bank from where soil was taken	Percentage by weight			
	Silt	Clay	Sand	Chemical
74-3-210 Left Bank	60	18.5	20	Calcium Carbonate 1.05%.
38-5-0 to 38-6 LB.	3	76	18	-do- 0.99%
52-2-0	72	7.5	18.7	Calcium Salts present.
30-0-200 Right Bank	4.2	50.2	42.0	Calcuim Carbonate 0.90%
38-6-0 to 38-7 R.B.	34.0	33.0	36.0	Not tested for salts.
Soils upstream of Hagari aqueduct (As tested at Poondi)	25%	20 to 40%	25 to 60%	0.4 to 1% Calcium carbonate and sodium chloride.

(e) *Existence of old stream beds silted up below the banks*:—These silted up beds allow free percolation of water below the foundation of the bank and cause settlement in the ground and consequently in the bank also creating favourable conditions for formation of cleavage planes for free percolation and piping. The piping may start under the foundation itself if the banks do not settle, or in the bank at any cleavage plane caused by settlement of the bottom portion. This condition existed at mile 36/6 where a breach occured on 28.9.53.

(f) *Existence of porous subsoil strata below the foundation of the bank*:—The porous strata permits free percolation of water under the bank. The ground and bank above the porous strata thus get soaked up due to upward pressure of percolation water in the porous strata below. Thus the whole ground and bank get sodden at the bottom and piping may start especially when the soil with which the bank is formed is silty clay, or where there are some weak spots in the bank. This happened at the site of breach at 7/5 of left bank.

(g) *Leakages along the sides of masonry*:—Where the junction between masonry and earth is smooth and where sufficient projection are not provided for preventing a continuous cleavage line piping is likely to occur. This might be one of the causes of the first piping at mile 3-0-0.

How Breaches and Pipings are Closed

(*a*) *Closing a breach*:—As soon as a breach occurs the flow of water should be completely stopped if feasible or reduced substantially by closing the nearest regulator and opening the escape upstream of the site, gradually.

A ring bund should then be formed immediately in a curved shape enclosing breached site for sufficient length to enable the required length of bund being reformed. It should not encroach too much into the width of the canals as that would create undue heading up and increased velocity which

may endanger the ring bund. It is easier and quicker to put up a ring bund when there is flow by first dumping stones under the water and raising it and providing it with an impervious facing with sand and clay bags.

Once the flow subsides it can be raised and strengthened rapidly by using the earth available nearby. If earth has to be conveyed from a long distance it is preferable to borrow it from the top free board portion of the bank itself. This can be made good later on leisurely. After putting up the ring bund the ground at the site of the breach should be stripped off properly by removing all sand, slush and loose stuff. A central cut-off trench sufficiently deep, say 3 to 4 feet below the existing scoured ground level (if the soil below is compact) or deeper still, say upto 6 feet (if the soil is sandy or loose), should be excavated. The width of the trench may be 4 to 6 feet. The trench should be refilled with select clayey soil, watered and consolidated well. If good clay is not available a masonry cut-off wall about 2 feet to 3 feet thick should be constructed. The puddle or masonry core-well should be raised upto F. S. L. The bund should be raised along with the core-wall using clayey material in front and gravelly or loamy soil in rear. The usual precautions, such as joining the old and new banks with steps and joggled recesses as specified in the M.D.S.S., proper watering and consolidation, should be taken.

Where time permits a masonry revetment may be constructed in front with a vertical toe wall taken down, to at least 2 feet below the deepest scoured ground level. If such a toe wall is constructed it will serve as a cut-off wall and no separate puddle core or masonry cut-off wall is then necessary.

Filter drains also should be provided at breach sites. One longitudinal drain along the rear toe of the bank or a little inside the bank with one or more cross drains to lead away the percolation water sufficiently far away. In cases where the soil or subsoil is gravelly and where heavy percolation is expected the cross drains may be extended up to the rear of the central core-wall. A substantial rear berm should be formed and the edges of this berm should be protected with rock toe.

(*b*) *Closing a piping*:—When piping starts and muddy water appears in the rear of the bank, quick action should be taken to control the piping. The level of the water in canal should be got lowered by regulating the escape and regulators immediately above. (As the ingress of some of the pipings may be just at or below the water level the piping may disappear with the lowering of water level). Simultaneously labourers should be asked to get into the canal and try locate the mouth of the piping, by walking along the slope under water. If it is a small piping it may stop even with the persons walking on the slope and trampling with their feet. If it is a larger hole it should be searched for and closed by sending in brushwood into the hole and then slipping earth from the top portion of the front slope and tamping by the feet of labourers. If the hole is big this will create a whirlpool near the ingress and can easily be located. Sand bags may be sent through the hole to block it up. The exit in the rear also should be blocked up by putting earth scrub jungle etc. It may then reappear a bit higher up. This also should be closed till the exit moves up higher and higher until the velocity at exit is controlled or flow stops. A ring bund or a front berm should be formed by slipping top earth above the free board, lower down. This earth may block up the piping hole and also will serve as a ring bund.

A masonry cut-off wall should then be constructed just at the junction of water surface and front slope of the bank sufficiently long to cover the weak portion on either side of the piping site and revetment constructed over this cut-off wall. This need be done only at the major piping sites.

It may not be necessary to stop the flow in the canal for blocking up the hole or for constructing front cut-off walls. These can be attended to even with the flow unless the piping is large.

After controlling the piping the tunnel of the piping should be traced from rear, the bank cut open at the site and reformed with good earth. The bank should be strengthened with revetment and toe-wall in front and berm and filter drains in rear just as in the case of breaches, depending upon the nature of piping.

PROTECTIVE AND PREVENTIVE MEASURES

The following protective measures have been taken; (*a*) Constant watch at sites of embankments and slipping earth from top portion of banks as the water level is increased and tamping front slopes to block the crevices formed due to initial settlement and blocking holes noticed when piping starts. (*b*) Construction of masonry or concrete slab revetments at sites where the soil is silty clay with deep toe walls to serve as cut-off walls. (*c*) Strengthening bank by forming substantial berms and filter drains in rear. (*d*) Filling the bed with clayey soil where the ground level is below bed level.

CONCLUSION

Embankments should not be formed out of silty clay soils without the necessary precautions such as:— (1) Stripping of all loose and pervious soil below the foundations; (2) providing cut-off walls either with puddle core or masonry taken down to reasonable depth below ground level; (3) providing masonry revetment for front slopes with toe walls taken down at least 2 to 3 feet below ground

level, or thick gravel casing not less than 4 feet thick; (4) filling up the bed where the ground level is below bed level with clay and gravel cover and consolidating the filling; and (5) prividing a flat rear slope and berms with pervious soil with longitudinal and cross filter drains below the berm and rock toe at the outer edge of berms.

These pipings are less likely to occur after the bank settle gradually after one or two years. But the pipings due to rat holes and presence of salts in the soil may occur at any time even later on.

Another trouble we are having in banks formed of clayey soils is that the front slope is getting eroded and slipping badly in several reaches. The front slopes are being eased at these sites and rear slopes strengthened. Though casing the banks with gravel will be better remedy it could not be resorted to due to prohibitive cost. The front slopes of cuttings in flumes which are not lined are yielding due to action of water and are slipping in some flumes. These may have to be lined ultimately.

The major embankments which were formed with proper selection of soils, cut-off walls and filters in rear have stood very well and there was absolutely no trouble even during initial trial run. Similarly where the soils used were gravelly even though there was profuse seepage in rear berms there was no trouble.

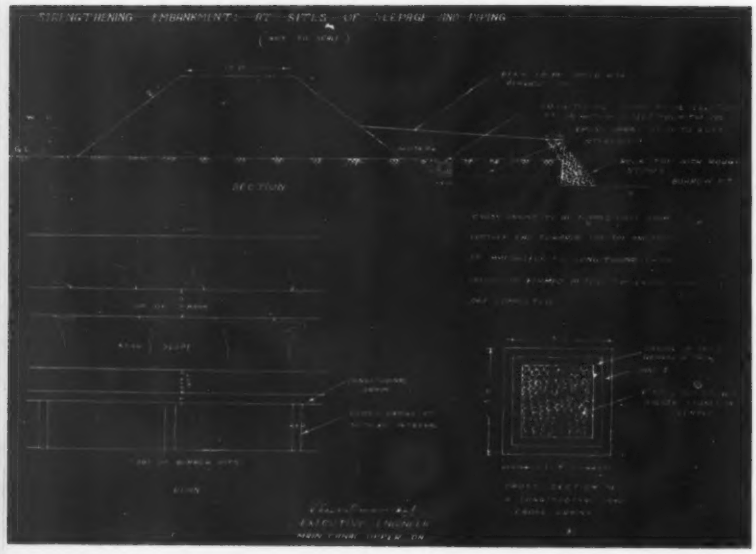
The trouble in the clayey banks was in the minds of the engineers who started the project, but to avoid prohibitive cost involved in conveying better soils from a distance or constructing revetments and cut-off walls, certain experiments were conducted and it was decided to use the soil available in the locality for forming the banks. No doubt this has involved certain risks and criticism at the hands of the public initially. But ultimately it will cost less to the department to undertake repairs and protective measures as found necessary at the weak spots where they show out during actual run of water than to have invested a large sum of money on precautionery measures indiscriminately before the trial run.

SPECIFICATIONS

Masonry Revetments 0′-6″ to 1′-0″ Thickness

The work corresponds to Random Rubble work as per M.D.S.S. But the quantity of mortar to be used works out to 40 cft for 100 cft of masonry for revetments 1′-0″ thick or less than 1′-0″ thick. As the available canal spals are used for the work there is no special dressing or necessity to provide bond stones for this work. The bottom portion of the revetment may be 1′-0″ thick upto about 1′-0″ above bed level in embankments. The thickness may be reduced to 0′-6″ to 0′-9″ according to the size of stones available for the top portion. The labour charges for masonry of toe walls also may be paid at the same rate as revetment for this class of work.

The revetment should be constructed over properly sectioned gravel backing. The bank should be sectioned properly and then provided with gravel backing not less than 6″ thick. Model sections 2′-0″ wide should first be constructed at every 20′ intervals to the correct slopes, the interior filled in later. The edges of the model sections may be finished smooth. The toe walls should be so built as to give a bevelled edge in the inside to provide a toe hold for the revetment as shown in the sketch.



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Cement Concrete 3″ Thick for Canal Lining

(*a*) For bed and (*b*) for slopes of banks using graded metal $1\frac{1}{2}$″ to $\frac{3}{4}$″ size in 4 : 1 proportion in C.M. 1 : 4 : 7 and finishing smooth.

The surface to receive the concrete lining should be sectioned, watered and tamped in the case of bed lining. In the case of slopes of banks gravel backing 6″ thick should be done and tamped properly and the surface wetted before laying concrete. A thin coat of cement slurry should be applied on the surface just before laying the concrete. The concrete should be in cement mortar 1 : 4 : 7 using $1\frac{1}{2}$″ to $\frac{3}{4}$″ size metal in 4 : 1 proportion. The surface should be tamped with wooden tampers or screeding tamplate and rubbed smooth using extra neat cement at the rate of $\frac{1}{4}$ cft for every 100 sq. ft.

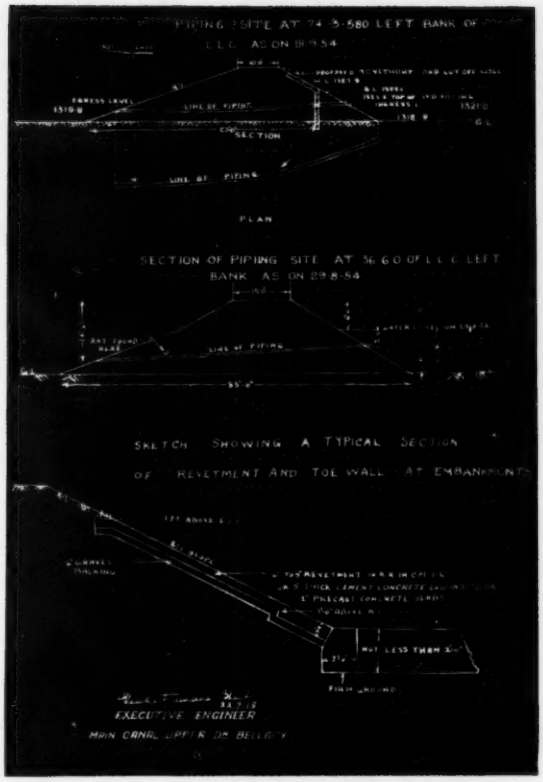
Model sections either with 6″ thick R.R. masonry or 6″ thick concrete and 1′–0″ wide shall be formed first dividing the area into 1′-0″×5′-0″ panels in the case of bank slopes. When concrete is laid for bed lining it should be laid in alternate panels 10 ft wide and half width of canal.

Manufacturing 2″ Thick Precast Cement Concrete Slabs 1 : 4 1/2 : 8 Proportion Using 3/4″ Hard Granite Metal

The slabs are manufactured in size 2′-0″×1′-6″ as this size is found in practice to be easy to handle without damaging the slabs and will be 2″ thick. (slabs of various dimensions and proportion such as $2\frac{1}{2}$″ thick and 2′-0″ square with graded metal $1\frac{1}{2}$″ to $\frac{3}{4}$″ size 1 : 6 : 10 and 1 : $4\frac{1}{2}$: 8 proportions were tried. But it was found in practice that $\frac{3}{4}$″ metal and 1 : $4\frac{1}{2}$: 8 proportion gives a better mix for concrete. The size of 2′-0″×$1\frac{1}{2}$″ and 2″ thick was sufficiently easy to handle also.)

Breakage was more when bigger sizes were used. Leaner mixes than 1 : $4\frac{1}{2}$: 8 also gave rise to more breakages.

The concrete is laid in wooden moulds tamped properly and top smoothened with a little extra cement. The mould can be released within 15 to 20 minutes. After they attain sufficient hardness the slabs may be removed and cured under water for a period of about 14 days. Before they are taken for curing under water they should be cured by covering with straw or clay or old gunnies and watering profusely.



4. Setting Precast Slabs in Position and Pointing with Cement Motor 1 : 4.

The slabs will be laid on the prepared gravel backing with $\frac{1}{4}$″ to $\frac{1}{2}$″ space in between the slabs and the joints grouted well with mortar for the full depth of 2 inches and top finished flush and smooth by trowelling. Weep holes may be left in the slab revetments by leaving one vertical joint out of every 10 without grouting in alternate courses.

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Man-made Malaria

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IN the course of an article entitled "Man-made Malaria in India" published in 1936 Lieut. Colonel J. A. Sinton, I.M.S., who was then Director of the Malaria Survey of India, made the following statement:—"In the construction of large engineering works, the engineer naturally tries to complete the projects as cheaply as possible consistent with technical efficiency, and often takes no heed of, or does not realise, the disastrous results to health and prosperity which may follow upon his operations".

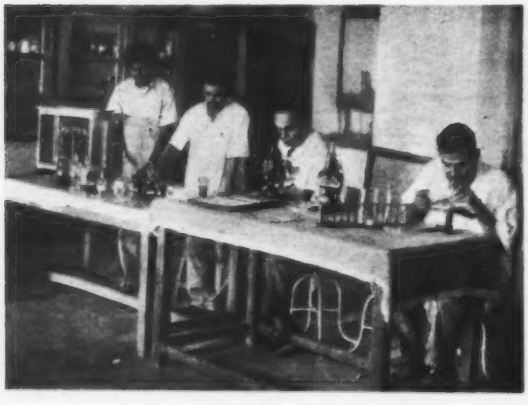
The urgent necessity for the institution of forceful measures to prevent the harm which is being produced by man-made malaria in India has been recognised for a very long time.

Clemensha, Sanitary Commissioner, in his memorandum before the Government of India in 1917 has stated that "the time has come when co-ordination between irrigation authorities and the Sanitary Department was pre-eminently desirable".

At the 12th conference of Medical Research Workers in 1934, it was resolved as follows:—"This conference notes the rise of malaria that has occurred as the result of the Sind irrigation project and regrets that the definite early warnings of the Malaria Survey in this respect had apparently gone unheeded. In future, in all provinces in India, before any irrigation or other major engineering projects are undertaken, there should be, where it does not already exist, compulsory co-operation between the irrigation or other departments concerned and the Public Health Department."

The Governor of Punjab, His Excellency Sir Herbert Emerson, in an address delivered in 1935 at the opening of the Punjab Engineering Congress, pointed out the tendency of Government departments to look upon problems from the aspect of how they affect the budgets of their own departments and not that of the province as a whole. He pointed out the necessity of co-operation between different departments in the interests of the finances of the Government as a whole and not of their own departments only.

Paul F. Russell states in his book on Malariology as follows:—"But it seems fair to ask why engineers are given budgets to bring great quantities of water into a region but at the same time are not provided with funds to remove this water by counter-drainage". He further states that "It is realised that many of the conditions which favour the increased incidence of malaria in connection with construction works are the direct responsibility of the contractors, and not of the engineers concerned. It is important, therefore, that, when contracts are given, clauses should be included to ensure that the contractor will not carry out his work in such a manner as to leave a trail of malaria behind."



Malaria Survey—Malaria Laboratory

Malaria Survey—Adult Mosquito Collection

Malaria Survey—Mosquito Larval Collection

John M. Henderson, Professor of Sanitary Science, Columbia University School of Public Health in his paper presented at the annual meeting, Research Committee, Central Board of Irrigation, in 1949, states as follows:— "The history of surface irrigation in India dates back many centuries. Until very recently construction methods appear to have shown no change over this period. The same head-carry methods, practised during the days of the Mogul Emperors have prevailed into the twentieth century, and are still widely used even in current constructions. This method of construction appears to be the greatest single physical reason for the extensive malaria caused by irrigation channels and by the borrowpits in irrigation, highway and railway constructions." He further states that "The regrettable thing about this blot on the engineering profession and this social blight is that every engineer the author talked with in India, is familiar with the malarial significance of the water holding borrowpit. Moreover, the drainage of most borrowpits does not require engineering design or supervision, but can be accomplished under the direction of mates, whenever instructions are issued and enforced." He adds that "The civil engineering profession has such a major potential role to play in preventing and abating malaria in this country that a thorough grounding in the rudiments of malaria control engineering is an essential part of the undergraduate training of every civil engineer, regardless of specialized interest".

Realising the importance of this problem in 1954, the Anti-Malaria Sub-Committee of the Central Board of Irrigation and Power gave a report, after going into the question thoroughly, suggesting measures that should be taken at various stages of projects to reduce malaria hazard. The Central Board of Irrigation and Power accepted the recommendations of the Anti-Malaria Sub-Committee and the recommendations were sent to State Governments and Project Authorities with a request that "The Board considered it most desirable that the suggestions made by the Committee should invariably be given effect to in all the stages of River Valley Projects."

With the experience gained in the construction of various projects in India much thought was bestowed before the Tungabhadra Project was taken up for execution to build out malaria in Tungabhadra Project and the following measures were carried out.

The need for a malaria survey of the area to determine the existing conditions and to decide the measures to be adopted was agreed to and the Rockfeller Foundation Team then operating in Pattukottai in Tanjore District was requested to examine the Tungabhadra Project area and to make suggestions for anti-malaria work. Dr. Paul F. Russell and Mr. Fred. W. Knipe of the Rockfeller Foundation studied the problem and presented an illuminating memorandum. The salient points in the memorandum were as follows:—

1. Since malaria was already a serious problem in the area it had to be dealt with undoubtedly for the protection of labourers during construction and for attracting colonists afterwards.
2. Advisability of the project designed, constructed and maintained in such a manner that malaria incidence was not increased.

They also stressed the imperative need to have close collaboration among Public Works, Public Health and Agricultural Departments.

As per their recommendation sanction was accorded for a malaria investigation unit to survey the area. The starting of a malaria control programme in the area immediately after starting of the investigation work without waiting for the commencement of work was also recommended and taken up.

The Chief Engineer for Irrigation, Madras had issued instructions on the location of borrow pits

Anti-malaria Operations—D.D.T. spraying

Anti-malaria Operations—Oiling

Filling up of pits

to all Public Works Department subordinate authorities. In a circular issued on 2.7.1940 he deprecated the location of borrow pits without reference to elementary requirements of drainage and directed that it was essential to dig borrow pits in such a way that they would be drained properly or rendered innocuous and those that could not be drained should be avoided.

The Government of Madras considered the report of the Special Officer submitted in 1948 and passed orders on the important recommendations as follows:—

1. Necessary instructions had already been given to construction engineers to avoid borrow pits and quarry pits forming stagnant pools.
2. They agreed with the Chief Engineer that as the canal ran in black cotton soil there would not be much seepage and when they occurred drainage would be provided.
3. The Government wanted the Chief Engineer to keep in mind that streams were not turned into sources of mosquito breeding.

The Government extended Chapter IX of the Madras Public Health Act, 1939, as a deterrent measure against creation of borrow pits.

The object of this paper is to focus attention on the importance of the close co-operation between the public health, engineering and allied sciences in order to prevent the creation of malariogenic conditions in river valley projects. The completion of the Tungabhadra Project without interruption and without creating the conditions of what has been termed "man-made malaria", has been possible solely due to the excellent and unstinted co-operation that existed between the concerned departments.

Lined canal.

(Continued from page 53)

[8] Quoted by T. V. Mahalingam from "A History of the Deccan" by Gribble.
[9] Quoted by T. V. Mahalingam in his "Economic Life in Vijayanagara" from E. I. XIV P. 94.
[10] Mysore Gazetteer Vol. III P. 164.
[11] Mysore Gazetter Vol. III P. 164.
[12] Bellary District Gazetteer P. 95.
[13] Bellary District Manual P. 231 and Bellary Gazetteer P. 95.
[14] Sewell "Forgotten Empire" P. 51, 301 etc.
[15] Reproduced from the Bellary District Gazetteer by W. Francis 1916.
[16] Siriguppa itself is a taluk now.
[17] Adoni is in the Andhra State after the States Reorganisation.
[18] The following details in inverted commas are from the Bellary district Gazetteer P. 96 & 97.
[19] Contributor apologises that the details regarding the anicuts and channels that served the left bank of the river could not be had readily, even after best attempts, to make this article more comprehensive.
[20] Quoted by W. Francis in his Bellary District Gazetteer.
[21] Bellary District Gazetteer P. 95.
[22] Mysore Gazetteer Vol. III P. 158.
[23] Sewell: 'Forgotten Empire' Account of Paes when describing the construction of a big tank (ref: above Rayara Keri).
[24] Ibid.
[25] Ibid.
[26] Epigraphic Carnatica Vol. X Goribidunur 6.
[27] I am grateful to the section officer, P.W.D. Kamalapur for the information.
[28] Rough stone masonry.
[29] E. C. VII Sl. 30 quoted by T. V. Mahalingam in Economic Life in Vijayanagara.

Ancient Anicuts on the River Tungabhadra

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GREAT boldness, ingeniuty and judgement are exhibited by the dams (known as anicuts in the local language, Kannada) that were laid across the rivers to raise their water to a higher level and convey the water through channels for irrigation purposes and thereby increase the agricultural production. These works are of great antiquity. As in earlier days of history, the Vijayanagar rulers and their subjects took considerable pains to improve the irrigation system of this agricultural country of scanty and uneven rains. As a result we see even to this day, many dams or anicuts built ingeniously across the river Tungabhadra during days of the Vijayanagar Empire, which are of great admiration even to the modern engineer. These are built to facilitate irrigation for the fields and gardens, and supply of potable water for the towns and cities of their land. Besides anicuts, construction of tanks and innumerable wells were also attended to for the same purpose. Sometimes such works were executed to provide potable water for the towns and cities. For example, it is stated that Bukka II got the Turutha anicut built and Turutha channel excavated to meet the water scarcity in the capital[1] and it holds good if one visits that spot. Again in 1388 A.D. a hydraulic engineer named Singeya Bhatta dug a tank to provide water to the city of Penugonda from the river Honne[2]. Many of their anicuts are still in use irrigating thousands of acres and are a great boon to the ryots of these parts. Of course, these anicuts ha e been repaired or improved to suit the needs of these days. But study of their attempt and success in these works is of great admiration.

India is a vast agricultural country depending greatly upon the favour of the rains which are quite often disappointing in one part or other of this vast country. From the earliest times in Indian History (from Ramayana and Mahabharata period) references to famines or droughts and the attempts of the rulers and other generous public to face or avert them are common and frequent. One of such attempts was to provide irrigation facilities and thus decrease the possibility of a famine and its effects on the welfare of the people.

IRRIGATION IN ANCIENT TIMES

Irrigation or watering the land through artificial means for raising the crops is three kinds, i.e., tanks, wells and rivers. All these three methods of irrigation have been known to us from at least the Vedic period as the Vedas (Rigveda, Yajurveda and Atharvaveda) mentioned the term that signify wells, canals and dams. Atharva Veda (III—13) gives description of digging canals from the rivers[3]. Kautilya of Arthasastra fame gives much importance to the irrigation works in the Indian polity. It is quite well known that Chandra Gupta Maurya and also Asoka are attributed to have constructed and repaired a large reservoir, called Sudarsana by damming up some of the streams near Girinara or Junagarh[4]. And when we come o the mediaeval period, great concentration was made on this work of artificial watering of the land both by the rulers and the generous public. The necessity for them was greatly felt during this period, probably because of the increased population both foreign and Indian, in the land. In this part of the South India, during the time of Chalukya, Hoyasala and Kakatiya rulers, innumerable tanks, wells and a few anicuts were executed for increasing the agricultural production for the good of the people. The same policy continued during the Vijayanagar period rather with greater impetus than before. There are a number of contemporary literary evidences, both oriental[5] and foreign[6]. Dealing with the irrigation works of Vijayanagara period, it is said that "almost every catchment basin, however small, still bears traces of having been bounded across and in many instances this was done in order to secure a crop of paddy on a few acres of stony ungenerous soil . . ."[7] Likewise, Sir Thomas Munro said: ". . . to attempt the construction of new tanks perhaps a more helpless experiment than the repair of those which have been filled up, for there is scarcely any place where a tank can be made to advantage that has not been applied to this purpose by the inhabitants"[8].

Great merit was attached to such works and it also had sanction of the religion or Dharma of the land. Undertaking of irrigation works was considered to be a part of their duty by the rulers of the ancient times. Ancient writers also laid much stress on this point. It is said that "digging of a tank is regarded as the greatest of the seven meritorious acts of the

man". In another instance, as recorded in an inscription, such an act was regarded that even Bramha was not able to recount the merits accruing from it, as that water serves to nurture both the movable and the immovable on the earth. Therefore not only the rulers but quite often, the public, the officers of the state and sometimes institutions like temples and Maths undertook the water works for the betterment of the land. There are several instances when the rulers realising the need of such works for a certain place, ordered or advised the public, local chiefs, or institutes to undertake and complete such of those works on assurances of special privileges, concessions or ranks. It is well known in these parts that a Veerasaiva saint named Siddarameswara of Sonnalapura (modern Sholapur) in 12th century A.D. joined by his followers went on constructing tanks and wells, with a firm faith to attain salvation (Moksha) therewith. This being the faith and belief of those days, even to this day we see a number of irrigation works of the olden days, constructed by various classes of the society and all over the country, inspite of the enormous limitations and draw-backs of that age comparative to the present.

CAUVERY'S OLDEST DAM

Of the existing old anicuts in this State, Mysore, the oldest are those built by the Hoyasala rulers of this region. "The large talked anicut, the lowest dam on the Cauvery, is said to have been constructed a thousand years ago . . .[10]. And the others that are found on the same river are said to be not less than three centuries old"[11]. Thus construction of the dams across the river for irrigation purposes was not new for the Vijayanagara generation and they simply carried on the same policy at sites of their requirements.

Vijayanagara rulers by a strange incidence (if we are to believe the tradition of a hunting dog bitten by a wild hare) and most likely due to the then prevailing circumstances, had to locate their capital in the neighbourhood of Hampi in this district. This area by nature is so full of ranges of hills, boulders and rocks that the fact makes one wonder at the Vijayanagar rulers selecting such a rugged site for their capital (it is not the purpose to deal with the point here). Soon the capital, with the royal patronage, peace and plenty in the kingdom, grew up enormously that the problem of potable water was to be solved. Besides, the agricultural produce of this part of their kingdom had to be increased to meet greater demands unlike in earlier days. Hence the water of the river Tungabhadra, the only perennial source in this district, had to be brought for use, apart from sinking of innumerable wells, and building of tanks and kuntes.

Though expensive, Tungabhadra river water was diverted through channels, after laying across the river a number of dams or anicuts at judiciously selected sites, There are still to be seen about thirteen such 'anicuts' in this district alone, on the river Tungabhadra. At certain times the builders met with failure as seen in the case of Modalugatti of Hadagalli taluk etc.

The tradition regarding the construction of these anicuts is that all of them were built by an officer Dhanayaka (Commander-in-chief) of the King Krishnadevaraya (1509—1529 A.D.) called Mudda who started his life as a herd boy to a Brahmin astrologer. Mudda first built Dhanayakana Keri (meaning the tank of Dhanayaka) probably the large tank even now known by the same name about twelve miles south-west of Hospet. And then he executed Tungabhadra channels and at last he is said to have been buried in the high embankment south of Hospet (apparently the Rayara Keri)[12]. There are also a few villages with good amount of ayacut area, called Muddapura, Muddalapura, etc., probably named after this traditional builder. Excepting in the case of the Vallabhapura anicut and the Turutha anicut, there are no sure evidences as to their date of execution, name of the builder etc. Vallabhapura anicut which now lies submerged in the Tungabhadra reservoir, was built according to an inscriptional record[13] from its neighbourhood in 1521 A.D., during the reign of Krishnadevaraya, the greatest ruler and builder among those who ruled from Vijayanagara. The Turutha anicut is said to have been built by Bukka II (1399—1406 A.D.)[14] to provide potable water for the capital and irrigation water for its gardens and fields. The rest of the anicuts are attributable to the period of Vijayanagar empire, from the point of their location, lay out, construction, materials used, the ayacut area they command etc.

Till recently about ten anicuts were in use of which three are submerged in the present Tungabhadra reservoir i.e., the Vallabhapura anicut, the Kurudagadda or Hosakota anicut and the Ramanna anicut. The channels namely Basavanna and Raya respectively, that took off water from the above two, on the southern bank of the river, are still kept alive by being fed from the present Tungabhadra reservoir. The rest that are down the Tungabhadra Dam are still used after necessary repairs etc. and are made more useful than before in this district.

The ten anicuts of this district, their channels and the length of each channel as stood in 1904 A.D. are as follows:[15]

S. No.	Tank.	Name of anicut.	Name of the channel leading from it.	Length of the channel in miles.
1.	Hadagalli,	Vallabhapura.	Basavanna.	15
2.	Hospet	Ramanna		
3.	,,	Kurudagadda or Hosakota.	Raya	20

S. No.	Tank.	Name of anicut.	Name of the channel leading from it.	Length of the channel in miles.
4.	Hospet	Bella or Hosuru.	Bella	3
5.	,,	Turuttu	Turuttu	12
6.	,,	Ramasagara	Ramasagara	10
7.	,,	Kampli	Kampli	12
8.	Bellary.	Siriguppa[16]	Siriguppa	5⅞
9.	,,	Desanuru	Desanuru	5
10.	Adoni[17]	Ramapuram	Ramapuram	10¼

A few other details regarding each of these anicuts are given below[18].

(1) Vallabhapura anicut, as seen above, was built in 1521 during the reign of Krishnadevaraya of Vijayanagara. It was about twelve miles west of Hospet. The dam was about 990 feet long from the southern bank to an island in the river and from that island to the northern bank of the river, there was another anicut known as Koragallu anicut[19] with an off-taking channel to irrigate the lands on the northern bank. The channel on the right side of the river is called Basavanna channel. As the anicut now lay submerged, the original Basavanna channel now takes off water from the Tungabhadra reservoir for irrigating the original ayacut area and more.

(2 & 3) Ramanna, Kurudagadda or Hosakota anicuts:—It "runs between the upper end of the Kurudagadda island and the further bank of the river and was designed to drive the stream between the island and the Bellary bank so as to increase the supply at the Kurudagadda anicut. This is three miles lower down, runs from the Bellary bank to the island and is 250 yards in length. The Raya channel which takes off from this anicut is the most important of the whole series. After irrigating about 4,000 acres, it ends in the Kamalapuram tank". This also, like Vallabhapura anicut, lay submerged and the channel is fed by the present reservoir as seen above already.

(4) Bella or Hosur anicut:—"This anicut is about two miles down the present Tungabhadra Dam where the river's course is from south to north. The structure runs across the eastern or the two branches into which an island there divides the river. The western branch is crossed by a ledge of rock which serves as a natural anicut. The dam is about 1,000 yards long".

(5) Turutta anicut:—This is known by the name because, the current in the channel is 'Turutha' (i.e. swift) and it is really so. "Bukka II, the fourth ruler of the Vijayanagar empire who ruled from 1399—1406 A.D., improved the capital, its water supply both for men and gardens by making a river channel flow through it—apparently the Turutta which is still to be seen flowing through the ruins of Hampi irrigating a good part of the land as it flows. This channel has been made to take off water by damming the river with big boulders and according to the story he (king) threw in a stone so great that it alone made the river follow the king's will. It was dragged thither by a number of elephants . . . by means of this water they made round about the city a quantity of gardens and orchards and great groves of trees and vineyards . . . and many plantations of lemons, oranges and roses"[20]. This anicut is built in ten sections utilising the huge rocks and boulders that are in the river itself which is dealt below. The length of the anicut is about 1227 feet.

(6) Ramasagara anicut:—It is called Ramasagara, though it is very near to another village called Bukkasagara. On the other bank of the river, it is known as Hira Jantakallu anicut. This anicut runs diagonally across the river for about a mile, making use of the islands and boulders that are in the river and similarly another embankment from the other side of the river. Thus the dam is complete and the channel from it is in places led across the Kampli channel by pipe acqueducts to irrigate the high level lands on the left bank of the latter.

(7) Kampli Anicut:—This is the last but another important one of them in this Hospet taluk. On the other side it is called Chikka Janatkal anicut. This anicut is 1¼ miles long, running diagonally upstream for some distance and then straight across to the other bank. It waters the land round Kampli And at some places, as seen in the above para, it crosses the Ramasagara channel.

(8) Siriguppa anicut:—It "is opposite Kenchanagudda. It is in all three miles long, but the actual masonry is only two miles in length, the anicut being built is seven different sections across the seven streams into which the river here is divided by rocks and islands".

(9) Dasanuru anicut:—It "stands at the head of the island of the same name, about half of a mile further down. It is 800 yards long and intercepts only four of the seven streams. Its channel runs lengthwise through Dasanuru island, at the lower end of which it joins the river". Of all the islands of the Tungabhadra river, Dasanuru is the biggest with a village by that name and the area is richly cultivated with the help of the channel that takes off water from this anicut.

(10) Ramapuram anicut:—"It is about a mile in length and its crest is so irregular that even in the dry season much water runs to waste over the lower portion of it. For the first six furlongs the channel from it is so near the river that there is not room between the two for a sufficiently large flood bank, and when the river is high, this part of the channel is submerged."

There are remnants of other anicuts at Modalakatta in Hadagalli taluk, Sugur in Bellary taluk and Mantasala in Adoni taluk, where the attempts met with failure. Moddalakatti, as its name suggests

in the local Kannada language (Modalu=first, Katti=embankment) is the first of the anicuts built across the river Tungabhadra by the Vijayanagar rulers. There used to be temporary dams across small streamlets, made up of tree trunks, branches, other vegetation, rubbles, sand, earth and whatever massy was available. These were washed away at every time of the floods in the stream, which had to be embanked afresh after the floods subsided, at enormous cost of labour, time and money. And incidentally if the floods were to continue for a long time, the crops had to wither away for want of water. Certain streams were embanked and converted into a tank. For example, Narihalla is dammed up to form the Daroji tank. "After discharging from this (Daroji tank) the Nari vanka runs on . . . irrigating as it goes, from seven small anicuts."

Generally the banks are high, the bed is deep and the land is sloping towards the river sharply. Hence the perennial water of this river could not be better made use of even after the construction of these anicuts and excavation of channels, in comparison to the time and money that might have cost them. All the above anicuts, channels, put together, irrigated about 16,400 acres of land as recorded[21] in the Gazetteer in 1904 and by 1930 A.D. required repairs and improvements were carried out to these anicuts and the length of the channels was increased wherever possible to irrigate a few hundred more acres of land.

A study of these anicuts reveals that the success which resulted from the construction of the works that are still in use was not obtained without a very large proportion of failures and the perseverance displayed by the construction inspite of the failures is none the less remarkable and shows the high value placed in former ages on irrigation works[22]. The works were completed by engaging thousands of men and carts for years at enormous cost[23]. As revealed in a number of inscriptions of the time, the rulers, the officers of the state, nobles, public institutions and quite often public of the land, voluntarily or otherwise undertook such works. The rulers encouraged private or institutional undertaking by showing concessions, grants, ranks etc., as already explained above. It is said the captives of war were also forcedly employed for the purpose[24], especially the experts. Such huge works cost a number of human and animal lives because of the accidents that were mainly due to the absence of modern mechanical devices. It is also stated that animal as well human sacrifices, sanctioned by the belief and scriptures of those days were common[25].

The sites for the building of these anicuts were located after mature thinking and judgement by the hydraulic engineers referred to as Jalasutra in an inscription.[26] Generally these engineers were brahmins well informed in other sciences too. The works were executed under their personal guidance and supervision, assisted by many aprentices, disciple students and the state.

The sites so selected are generally nearer the narrower width of the river with rocky banks, islands, huge rocks and massive boulders, the existence of which were taken advantage of by joining each of them with a section of masonry wall. Thus we see many sections of walls, plus the islands, rocks, boulders or all of them making the anicut complete. For example the Turutta anicut which is still in use is as follows from the right bank of the river[27].

Right bank of the river R. S. Masonry 28.81 feet Sheet rock R. S. Masonry (13 feet) hillock—R. S. Masonry, R. S. Masonry backed by R. S. Boulder. (210 feet) Big boulders (210 feet) Big boulders R. S. Masonry (15 feet) (high rock R. S. Masonry (40 feet) High rocky ground R. S. Masonry (150 feet) high ground R. S. Masonry (63 feet) Sheet rocks R. S. Masonry (231 feet) Sheet rock R. S. Masonry (15′-6″) sheet rock R. S. Masonry (60 feet) Hillock R. S. packing (109 feet) hillock (left bank).

And these anicuts did not necessarily run straight across the river "excepting the Turutta and the Vallabhapur anicuts. The others "run diagonally or in zig-zag across it (the river) utilising to the utmost any ledges of rock, small island or large boulders which the bed happens to contain".

Deep excavations were not necessarily made in laying the foundation for these anicuts. Quite often the selected sites were of sheet rock and the lowest course was embedded in the sheet rock after making a sort of groove lest the stone may easily be disturbed by the velocity of the current. Sometimes lime-concrete was also used in laying the foundation; the lime concrete of those days stands good in a number of instances even to this day. Use of stone pegs, fixed in the sheet rocks was well known to them to keep them in position.

At the bottom heavy boulders, while on the top little smaller rough stones, have been used. It is all rough stone masonry. These stones are of such size and weight, one is wonder-struck, as to how those people were able to handle them inspite of the limitations as for mechanical devices. Though there are no even sized courses of structure, the stones or boulders used were so properly dressed to receive or fit in exactly while retaining many angles. This technique can be seen also in the fortification walls etc. of this period. The technique made them not to think seriously of the use of any binding material. Use of lime-mortar and lime-concrete was very well known to them but they did not necessarily use in these anicuts which is a point of weakness of these structures. In earlier days of summer, the water in certain sites leaked through and in others this leakage was checked up by the silt that accumulated there. Thus this river silt proved to be a water

tightening media. Quite often iron clamps and stone pegs were used to keep the components of the structure in position. For example, in the Ramanna anicut stone clamps had been used while in the Siriguppa anicut iron clamps are to be seen[28] (Use of iron clamps in Indian architecture is not new with Vijayanagara people alone.)

There seems to have been no marked difference between the width at the bottom and the width at the top. It varied from 6 feet to 5 feet at the bottom and five feet to four feet at the top. Besides, here and there may be found packing of heavy boulders at the back of the structure. The difference between the thickness of the bottom and the top is so slight, probably because they are not of great height. The height varies between six feet and four feet. The top is plain without any special coping and the water flows over it.

The anicuts are not containing any sluice, gates or others of their kind to regulate or control the flood system in the river. After the water reaching the crest level of the anicut, whole of the inflow flows over the structure. The structures also, in most cases have withstood all the velocity of the current because of their limited heights. The off-taking channels also did not have any regulators at the starting points. The regulators or a sort of sluices were in use only at the distribution point.

The use of different kinds of sluices was very wellknown to the Indian hydraulic engineers from the ancient times as seen in the literary works of earlier periods. For example, long slabs of stones were made to stand on one of their sides in the midst of the channel to blockade the flow of water; and any leakages from the sides of the slabs were checked up with packed mud and vegetation. Sometimes a slab with a rough round hole was fixed vertically in the channel. When the water was to be diverted, the hole in the slab was closed with another smaller slab and mud packing or with a big wooded peg and mud packing. In the case of tanks a different mechanism seems to have been adopted. Two posts were fixed in the tank bed with horizontal slabs at two or three levels as seen even in the present days. From the point of these posts to the end of the tank bund at the lower end a tunnel was formed for the water to escape through. At the points of these two pillars a slab with a round hole was fixed horizontally to the top of the tunnel. A wooden bob like thing hung from the horizontal slabs of these pillars. When the flow-out of water was to be stopped the bob was let go down and sit in that hole tightly. This sort of regulation system seems to be still in use in the Daroji tank. Besides all these methods, use of sliding wooden planks was also known to them as clearly seen in a few of the aqueduct remnants in the Hampi ruins. Still, it can be said that regulation system was not perfect and there was much wastage of water.

The distribution system of water was quite interesting in those days. There was a village servant called Neeraganti whose work was to look after the regulation and distribution of water. He was also to report to the concerned about the special repairs and maintenance of the anicuts and channels. Minor works were carried out by himself sometimes assisted by the ryots. He was the guard on duty both night and day as per the needs. His service was for life and usually hereditary. For this, in the beginning itself he was given a grant of land and other concessions. He was also paid in kind by the royts of the locality. In return for this, he was also in charge of watering of each land irrespective of the interest shown by the owners. In his duty of this kind, he was bound by the Dharma of the country. Till recently this Neeragati was in charge of the rural irrigation system of these parts.

In some other cases, provision was made, at the time of construction, for its maintenance and special repairs. Usually such duty was entrusted to a responsible group of persons of the locality, or public institutions like temples and Maths or even local Panchayats. Whoever realised the need of the special repairs, undertook such works voluntarily or entrusted it to some one else. Because undertaking of such a work was regarded, as in the case of construction or digging of tanks, wells etc., as one of the great meritorious deeds. An inscription of 1413 A.D. states "A ruined family, a breached tank or pond, a fallen - Kingdom, who restores or repairs a damaged temple acquires merit fourfold of that which accrued from them at first[29]. Sometimes the community undertook such special repairs when there was need for such. And if at all there was any tax to meet the maintenance expenditure, it was purely local, agreed upon by the local Panchayat without the interference of the state.

Thus we see that the Vijayanagar period saw a number of expensive projects coming up for the betterment of the economic life of the people. They bear witness to the enlightment of the beholder, as seen above.

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[1] Sewell: Forgotten Empire.
[2] E. C. X Goribidanur 6.
[3] Irrigation in India through Ages by Sri Satya Sharava, M
[4] "History and Culture of the Indian People" Bhavans Vol. II, Page 87.
[5] For example: Amuktamalyda of Krishnadevaraya, the greatest ruler of the Vijayanagara Empire, states in canto IV, V 236 that the prosperity of the Kingdom would increase when tanks and canals are constructed for irrigation etc.
[6] Paes and Nuniz the Portuguese chroniclers refer to the construction of a big tank with the help of a Portuguese engineer Jao Della Ponte. Ref: Sewell "Forgotten Empire" P. 266.
[7] Crole "Changulput Gazetteer". This District formed part of Vijayanagara Empire in those days.

(Continued on page 48)

Tungabhadra Project: A Perspective

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TUNGABHADRA is one of the major tributaries of river Kistna which is the second biggest river in South India. Tungabhadra derived its name from the two tributaries "Tunga" and "Bhadra". These two tributaries originate from the same hill known as "Varaha Parvata" bordering South Canara district in Mysore State high up in the Western Ghats. They take different courses before uniting at Kudali, a village 8 miles from Shimoga in Mysore State. The river is 400 miles long and joins river Kistna near Kurnool in Andhra Pradesh. The river is famous both mythologically and historically being connected with the mythological epoch of Ramayana where the river is mentioned as "Pampa" and by nourishing the famous Vijayanagar empire on its banks which flourished in the 15th century.

Out of its total length of 400 miles Tungabhadra for about 100 miles in the end flows with the districts of Bellary and Kurnool on the right and Raichur district on the left. These districts together with Cuddapah and Anantapur districts on the right side are known as Rayalaseema and "Raichur doab" on the left side. These tracts are ill-fated having "scanty rainfall", which averages 20 inches per year. Even this scanty rain is not uniform and there were years when it completely failed. The tract, though very rich in soil, the maximum area being rich "black cotton soil", due to the vagaries of the rainfall was subjected to severe drought and famine conditions. These famines have become a natural phenomenon in these districts which were completely sapping down the populace of this area both physically and financially. This was also a drain on the State revenues as they have to protect the populace from famine by way of relief works etc. This is the main reason that suggested the Tungabhadra Project.

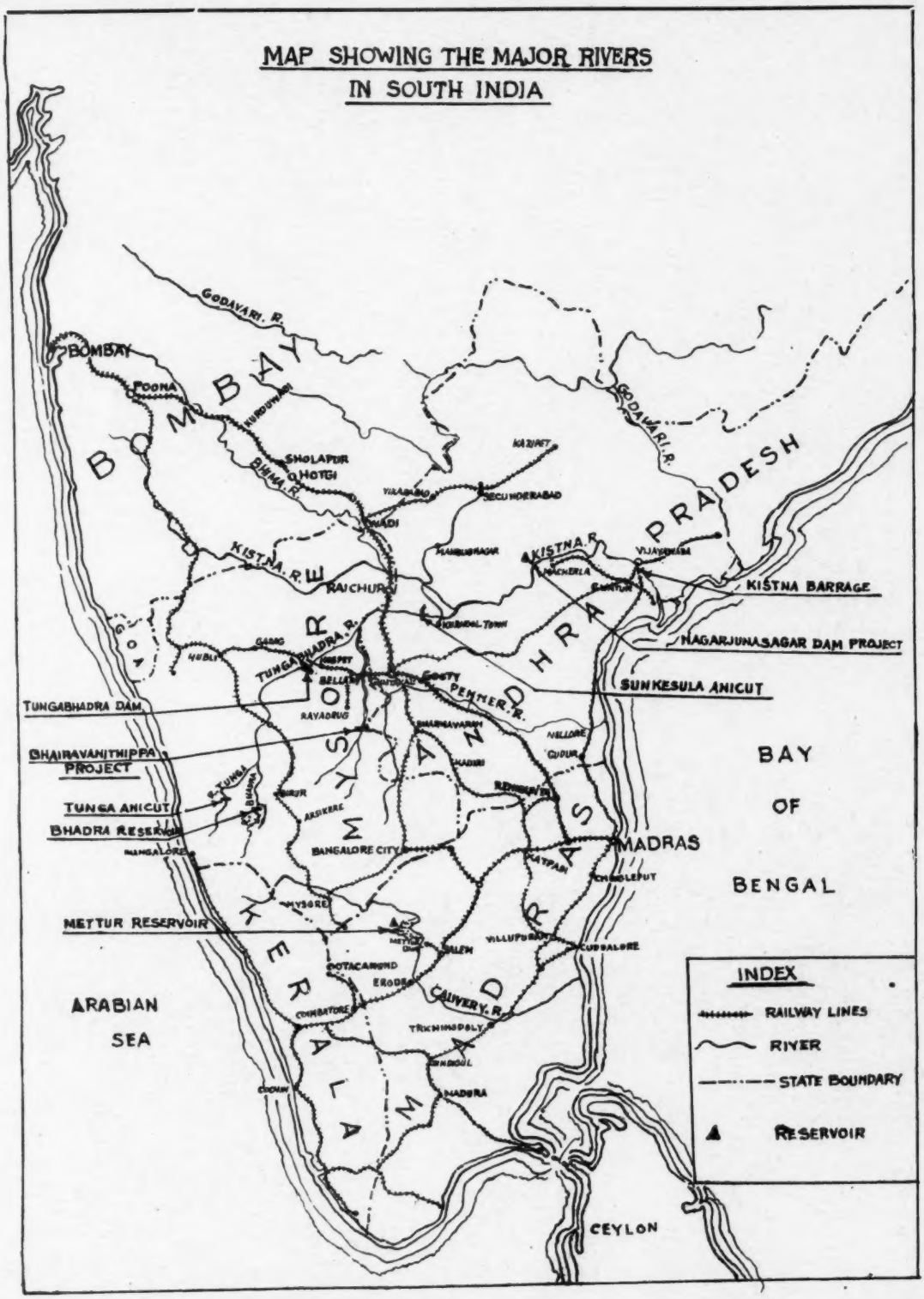
Stretches of barren land with black cotton soil

This river which originates in Western Ghats receives a maximum rainfall of 60 inches per year mostly by south-west monsoon mainly during a period of 2 months in the rainy season. This heavy incidence of rain causes heavy floods in the river during a period of 2 to 3 months and dwindles down to that of a small rivulet during the balance of the year. This naturally called for a storage reservoir which can store water during "flood season" and ensure regulated supplies during other periods.

Potentialities of Tungabhadra river were recognised even long back as seen from the ancient channels that take off from both sides of river. Ther5 are 17 such channels and these irrigate about 28,68a acres in Mysore State and 1,350 acres in Andhre State. These canals utilise only a fraction of the flows available in the river.

EARLIER INVESTIGATIONS

The investigations of modern age actually started as early as 1850. Sir Arthur Cotton, the irrigation wizard of South India, first conceived the idea of Tungabhadra Project which includes Kurnool—Cuddapah canal and the Bellary projects. The Madras Irrigation and Canal Company which contemplated the execution of these schemes, constructed the K. C. Canal in 1861 and did not attempt the other schemes. K. C. Canal after the remodelling recently done can irrigate 3,00,000 acres. Thereafter several schemes were investigated and reported till 1942. Of all these reports, the report prepared by Sir Mackenzie in 1902-06 was the best. This scheme consisted of a plan at a cost of Rs. 17 crores which included the benefits to Nellore area. This scheme was again examined by Mr. L. A. Smith who prepared a scheme for Rs. 13 crores excluding Nellore area, inclusion of which was considered uneconomical. But during 1908, Madras Government gave preference to Krishna and Cauvery projects and


MAP SHOWING THE MAJOR RIVERS
IN SOUTH INDIA
GODAVARI R.
BOMBAY
POONA
KURDUWADI
SHOLAPUR
HOTGI
BHIMA R.
BIJAPUR
KAZIPET
SECUNDERABAD
GULBARGA
KISTNA R.
RAICHUR
KISTNA R.
MAHBUBNAGAR
NALGONDA
VIJAYAWADA
KISTNA BARRAGE
NAGARJUNASAGAR DAM PROJECT
SUNKESULA ANICUT
GOA
HUBLI
GADAG
TUNGABHADRA R.
HOSPET
BELLARY
ANANTAPUR
GOOTY
PENNER R.
TUNGABHADRA DAM
RAYADRUG
BHAIRAVANITHIPPA PROJECT
CUDDAPAH
NELLORE
MADRAS
BAY
OF
BENGAL
TUNGA ANICUT
BHADRA RESERVOIR
SHIMOGA
TUNGA R.
BHADRA R.
CHITRADURGA
ARSIKERE
BANGALORE CITY
KOLAR
CHINGLEPUT
MANGALORE
METTUR RESERVOIR
MYSORE
METTUR DAM
SALEM
VILLUPURAM
CUDDALORE
COIMBATORE
ERODE
KAVERY R.
ARABIAN
SEA
TRICHINOPOLY
MADURA
COCHIN
CEYLON
INDEX
RAILWAY LINES
RIVER
STATE BOUNDARY
RESERVOIR

therefore did not submit Tungabhadra Scheme to Government of India.

Again in 1930 a modified scheme for a reservoir at Thimmalapuram about 35 miles above the present dam-site at Mallapuram was investigated. At this stage a proposal for a joint dam project covering Hyderabad also was mooted. The present site at Mallapuram was considered suitable for this purpose. Preliminary discussions on the new scheme were initiated. Between 1933 and 1936 talks were in progress between Madras and Hyderabad Governments. After a series of conferences and protracted correspondence, certain agreements were concluded between the various States concerned and the Madras Government in 1940 ordered detailed investigation. Accordingly detailed investigations were carried out and detailed report with detailed plans and estimates were prepared and submitted by Sri M. S. Thirumale Iyengar in 1942. The Hyderabad Government in their turn perpared a similar report and after a series of conferences the final agreement was reached between Madras and Hyderabad Governments in 1944. The Project was then sanctioned and soon after, the work began in February 1945.

THE TUNGABHADRA PROJECT

1942 report prepared by Sri M. S. Thirumale Iyengar conceived a dam across the river on the right side at Mallapuram and two schemes for canals. One of these was for a Low Level Canal and the other for a High Level Canal. The Low Level Canal Scheme provides for generation of power also in two stages. The Low Level Canal called the Low Level Canal Upper, runs on contour and feeds lands in Hospet, Bellary, and Siruguppa upto its infall into the Hagari river. The Low Level Canal Lower takes off from the right side of the Hagari river and irrigates lands in the Alur, Adoni, Pathikonda and Kurnool taluks. The High Level Canal Scheme provided for a main canal upper from the right flank along the Mackenzie's line upto 59th mile near Bellary where the water is dropped into a natural drain south-west of Bellary which joins Hagari river. This canal will be coupled with the main canal lower as per the Low Level Canal Scheme mentioned above. As an alternative to this another canal taking off from an anicut across Tungabhadra at Rajolibanda to feed 78,240 acres was also investigated in detail.

The Government of Madras chose the present Low Level Canals Scheme as mentioned above with sluices at +1550.00 with the modification that without dropping the Low Level Canal Upper into Hagari and Low Level Canal Lower taking off from Hagari on the right of Hagari, the canal is carried on Hagari by an aqueduct. For needs of High Level Canal 10 vents have been provided in the dam on the right side at +1585.00.

Similarly a scheme was drawn up on left side of dam providing canal of 127 miles long with sill at +1550.00. This canal also takes off from the tail race of turbines in the power house at the foot of the dam. There is provision in this canal also for generating power at three places along the canal, having various heads.

The dependable flow in the river is 336 units of thousand million cft. The distribution of the same is as follows:

		Units.
Dependable flow at the Damsite.		336
1. Bombay for proposed works.	1	
2. Madras Demand above Mallapuram:		
(*a*) Lakkavalli.	57	
(*b*) Tunga Anicut.	11.5	
(*c*) Proposed works (provisional)	10	
Total utilisation of Mysore above Dam:	79.5	79.5
	Balance:	256.5
Utilisation of water at Tungabhadra Dam as per 1944 Agreement:		
3. Hyderabad:	65.0	
4. Mysore & Andhra (Low Level Canal).	65.0	
	130.0	130.0
	Balance:	126.5
5. Krishna contribution:	26.0	
	26.0	26.0
	Balance:	100.5
H.L.C.		50.0
Net Balance:		50.5
Demand by Hyderabad (95.5-65)		35.5
		15.0

The reservoir formed by the construction of the dam has a gross capacity of 133 T. M. Cft. (3.05 million acre feet) at the full reservoir level 1633.00. The water spread area of the reservoir at F. R. L. +1633.00 will be 146 square miles submerging 89 villages and lands situated in the Mysore State. The reservoir when full gives a picturesque appearance with afforestation of the fore-shore and creation of wild life sanctuary. The reservoir is an ideal place for picnic parties with pleasure boating facilities.

The expropriated people of the villages submerged by this reservoir have been comfortably rehabili-

tated in other suitable areas in the fore-shore mostly, and along the new canals. They have also been paid reasonably adequate compensation for their interests lost. They have been helped in various ways, e.g. assignment of free sites for construction of houses, assignment of suitable lands for agricultural purposes and affording facilities for transportation of their families and personal effects, construction of schools, sinking wells, construction of village chawadies etc.

Headworks

The Headworks consists of a dam located, at Mallapuram near Hospet in Mysore State. This dam is one of the largest of its kind in the country and is third of the series of major river valley projects that were taken up for construction in South India in the first half of this century. It is the largest stone masonry dam at present in South India. The dam is a medium sized straight gravity type masonry dam. There is a central spillway section (ogee type) for passing the flood.

The total length of dam is 8006 feet, comprising the following sections :—

1. Non-spillway section.	..	3412 feet
2. Central spillway section	..	2300 ,,
3. Rolled earth-fill dam in the first saddle on left flank.	..	500 ,,
4. Composite dam in second saddle on left flank	..	1794 ,,
		8006 ,,

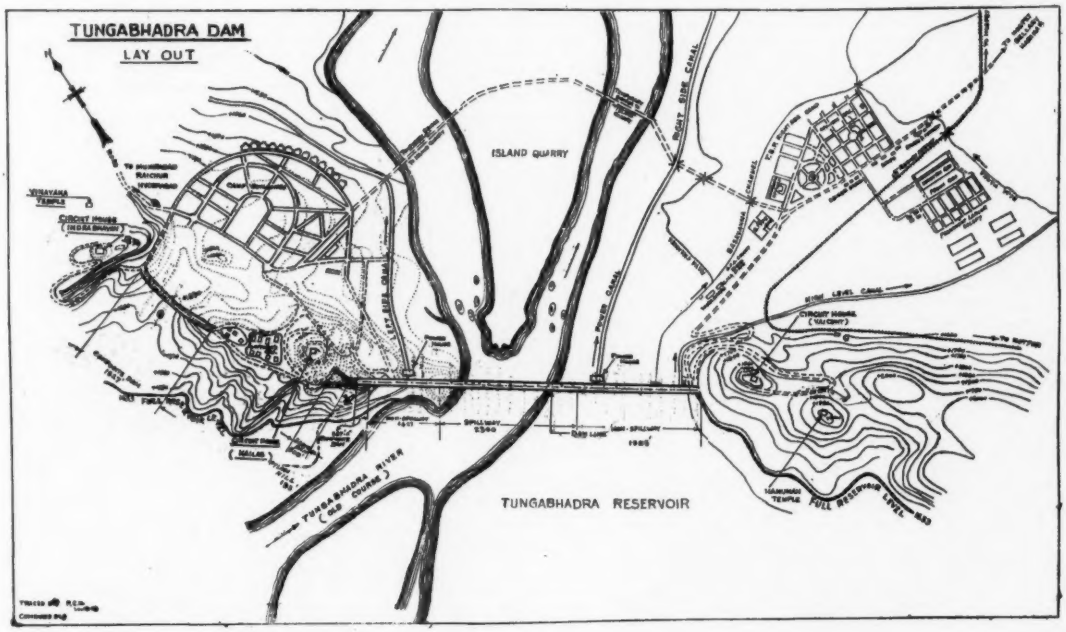
The maximum height of the dam over deepest foundation is 162'-0". The Tungabhadra dam is built in stone masonry the total quantity of which is 32 million cubic feet. The whole of the spillway section and the portions of non-spillway where the sluices are located are built in red cement mortar of different proportions and the remaining portion is in lime surki mortar. Proportions of mortars are as noted below:

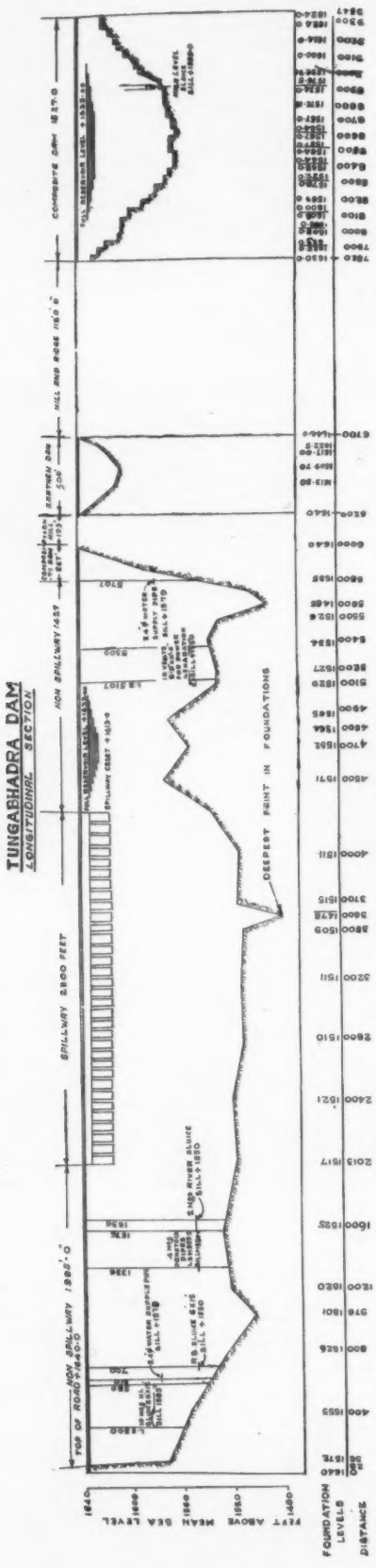
Red cement mortar: (1) 1:2¾, (2) 1:4 and (3) 1:5 Cement: sand by volume.

Lime surki mortar: (1) 1:1:1 and (2) 1:2:2 Lime: Surki: sand by volume.

Red cement used in red cement mortar consisted of 4 parts of portland cement to one part of finely ground surki, which is a puzzolanic material both by weight and each complying with its respective specifications. Addition of this puzzolanic material (surki powder) reduces the heat of hydration and help to keep down the cost of construction to the extent cement is replaced. The front 9'-0" is built in mortar of richer mix to ensure reasonable impermeability. The lower portion of the dam is built in mortar of higher strength than the upper portions.

The spillway design is of the ogee type with a curved bucket and depressed floor with baffle in the rear to dissipate the tremendous energy. A cement concrete apron beyond the R.C.C. faced baffle provides the necessary apron to prevent scours at the toe. The width of the apron varies



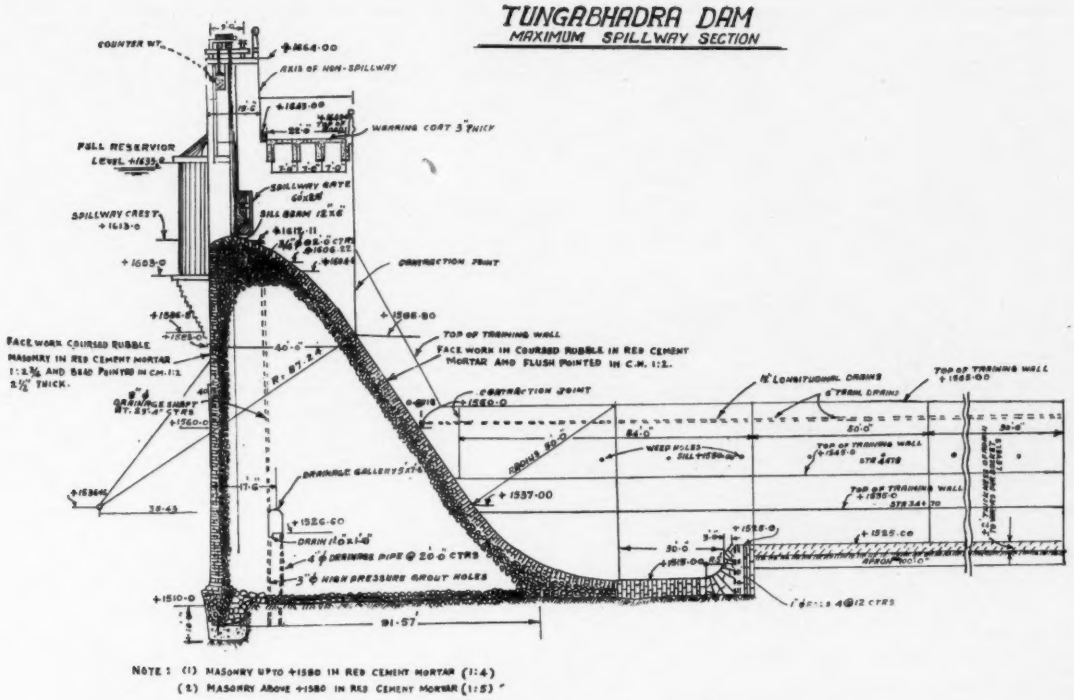


Tungabhadra Dam—Longitudinal section.

according to the nature of rock met with immediately after the baffle. The maximum width is limited to 100 feet. The spillway consists of 33 vents of 60 feet span and are regulated by shutters 20 feet high to pass a maximum actual flood discharge of 3,30,000 cusecs. But the spillway is capable of discharging 6,50,000 cusecs which is double the actual observed flood which ensures its adequacy. A road-way 22 feet wide is laid on the dam top throughout to provide communication facilities. The road-way in the spillway portion is laid on T. beam and slab decking on 10′-0″ thick piers of the spillway vents. Specially manufactured trusses 60′-0″ long were used for laying T. beam and deck slab.

There were two low saddles at the left flank of the dam one of which is closed by a rolled fill earth dam and the other by a composite dam. The composite dam has a masonry wall in front and earth backing in rear. The wall is constructed in the same way as the main masonry dam with foundations taken to rock. The earth backing is semi-pervious material with a slope of 2 to 1 on the down-stream side, horizontal beams being left at suitable intervals. The rear slope is protected by turfing. Horizontal graded filters at the bottom and loose rock-fill toe are provided in the earth-fill for proper drainage.

Foundation excavation in rock for dam.



Tungabhadra Dam—Maximum spill-way section.

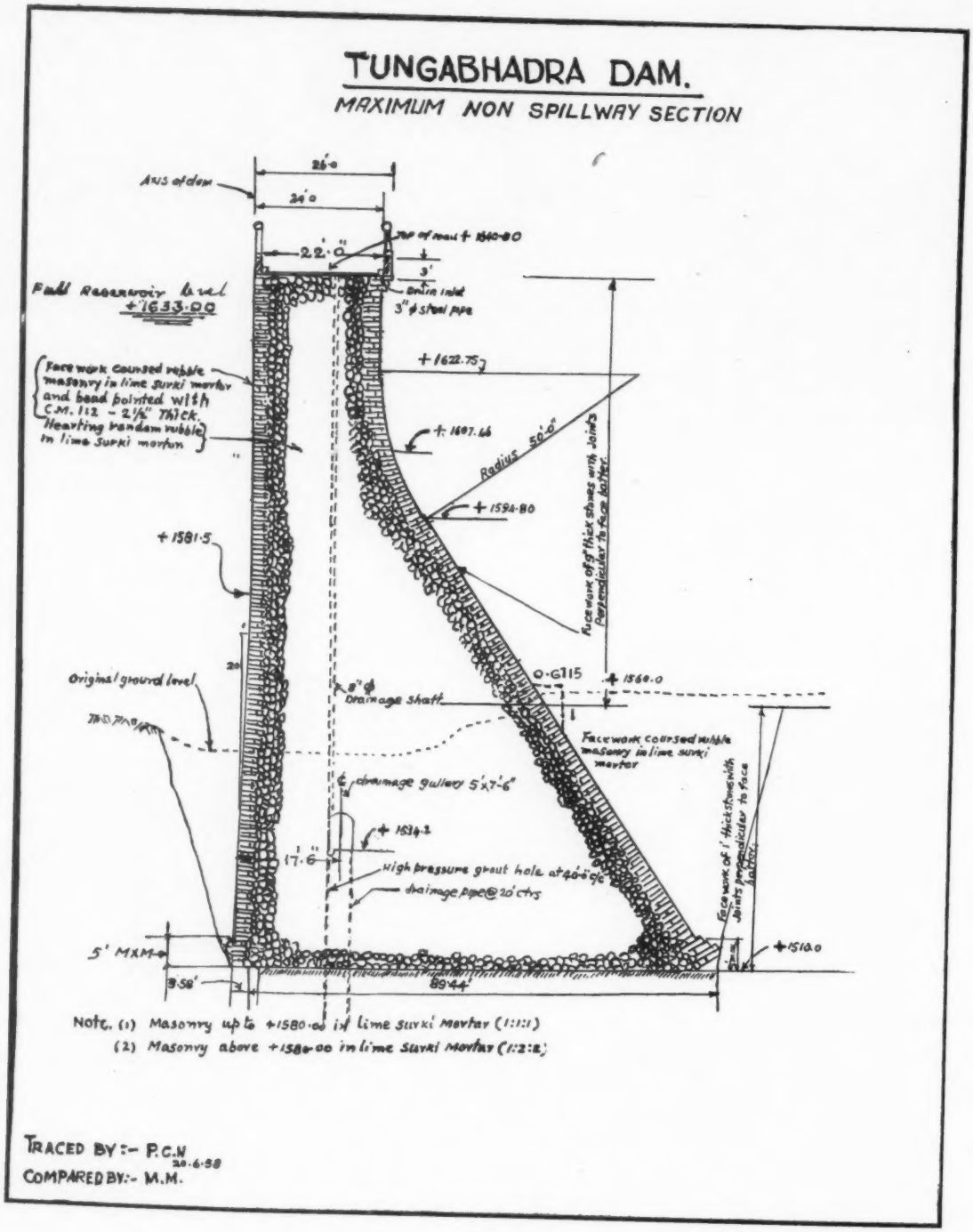
Excavation was done mostly in rocks after completely removing the top over-burden. The type of rock at the foundations consisted of very fine grained compact epidiorite schists and with a few narrow ribbons of ferruginous quartzite schists and reefs of pegmatites cutting through the epidiorite. The rock dips up-stream which special feature is of great advantage against creep.

Inside the masonry of the dam there is a drainage gallery 5′×7′-6″ with the floor at about 10 feet above the foundation rock level. The centre line of the gallery is at 17′-6″ down-stream of the axis of the dam and runs from one end to the other. Transverse galleries have been provided at either end of the spillway as approaches to the gallery. The rock foundation is drained into this gallery by means of a series of drainage holes. The collection of seepage past the impervious face of dam is accomplished by a series of vertical shafts of "Nofine" concrete ending the drainage gallery. A drain 1′×1′ depressed from the flooring runs along the gallery for leading the seepage water into suitably located pits from where it is pumped out. High pressure grout holes starting from the foundation rock end into the drainage gallery on the water face of the gallery. These holes are for the purpose of drilling and grouting of foundation rock. From the drainage gallery observations were made for the quantity of seepage water and free lime exudation. It is observed that 2.0 million cubic feet of water is seeping out, per year. This seepage water contains lime to an extent of 2.5% maximum and 0.4% minimum by weight in addition to free lime. The total lime that is exuded each year is 0.03% of the total lime used in the dam. As such by about 300 years the entire lime may be exuded. But as observed from year to year this percentage of exudation is on the downward trend.

Construction joints:—Construction joints at intervals of 93 feet 4 inches are provided with sealing strips of copper sheets gauge near both the up-stream face and the rear sloped face in R.C.M. sections.

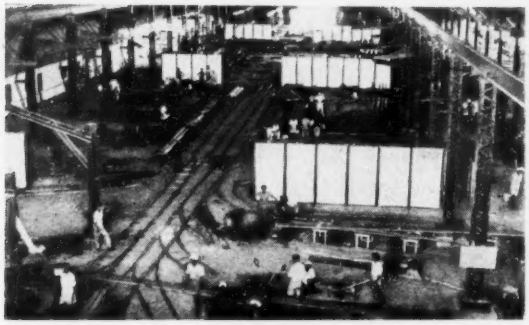
River diversion:—River diversion works consisted of coffer dams, regular and vented ones. The vented coffer dam zone was divided into three sections and water was diverted in any one of the desired sections. The deep river course consisted of 45′ gap 150′ wide at top. This was tackled in the summer of 1950 and before the rains set in masonry was raised to the level programmed.

Shutter Manufacturing factory:—One unique feature of the organisation here is the institution of Shutter Manufacturing Factory for this project, which was able to manufacture the spillway shutters of the dam and canal regulators for which till now we were


TUNGABHADRA DAM.
MAXIMUM NON SPILLWAY SECTION
26'-0
24'-0
Axis of dam
Top of road + 1640-00
22'-0"
3'
Full Reservoir level +1633.00
Entire inlet 3" ϕ steel pipe
+ 1622.75
Face work coursed rubble masonry in lime surki mortar and bead pointed with C.M. 1:2 - 2½" Thick. Hearting random rubble in lime surki mortar
+ 1607.66
Radius 50'-0"
+ 1594.80
Facework of 9" thick stones with joints perpendicular to face batter.
+ 1581.5
20'
Original ground level
8" ϕ Drainage shaft
0.G.T.L.15
+ 1560.0
Facework coursed rubble masonry in lime surki mortar
Drainage gallery 5'x7'-6"
+ 1534.2
17'-6"
High pressure grout hole at 40'-0" c/c
drainage pipe @ 20' c/s
Facework of 1' thick stones with joints perpendicular to face batter.
+ 1510.0
5' MXM
9'-58"
89'-44"
Note. (1) Masonry up to +1580.00 in lime surki mortar (1:1:1)
(2) Masonry above +1580.00 in lime surki mortar (1:2:2)
TRACED BY :- P.C.N 20.6.58
COMPARED BY:- M.M.

Tungabhadra Dam—Maximum non spill-way section.

looking for foreign manufactures. This has proved a great boon and a veritable gold mine for the country as it has undertaken manufacture of gates required for serveral projects in the country, on a commercial basis. This is the first of its kind in India and was



Shutter Manufacturing Factory.

inaugurated by the Prime Minister in September 1952.

CANAL SYSTEM

Right side canal—(Mysore-Andhra Side)

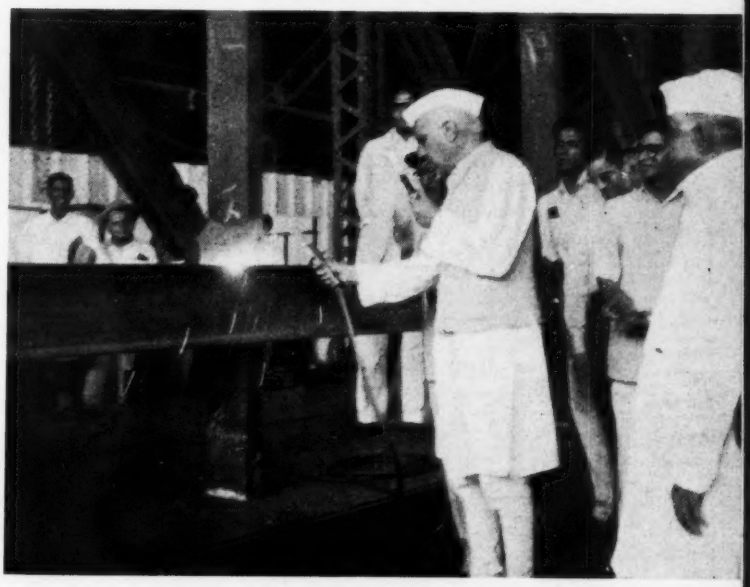
The canal is divided into two reaches called (*a*) Power Canal and (*b*) Low Level Canal.

(*a*) *Power Canal*:—The tail race of the water discharged from the power house turbines situated at the base of the dam on the right side of the river is the starting point of Power Canal. This canal runs 14 miles and enters the forebay from which waters are drawn through steel pipes 18′-0″ and to drop 110′ and develop power at Hampi. This Power Canal carries 2,500 cusecs. The Canal in this reach mostly runs in cuttings, the maximum cutting being 58′-0″. The entire Canal is lined to avoid seepage. The tail race of the Hampi power house discharges into Gundlakeri valley. This valley which receives 2500 cusecs from the tail race of the power house stated above, discharges 700 cusecs back into Tungabhadra through Gundlakeri vanka through a regulator and feeds the Low Level Canal with 1800 cusecs through another regulator at the head of the Low Level Canal. There is no irrigation under Power Canal.

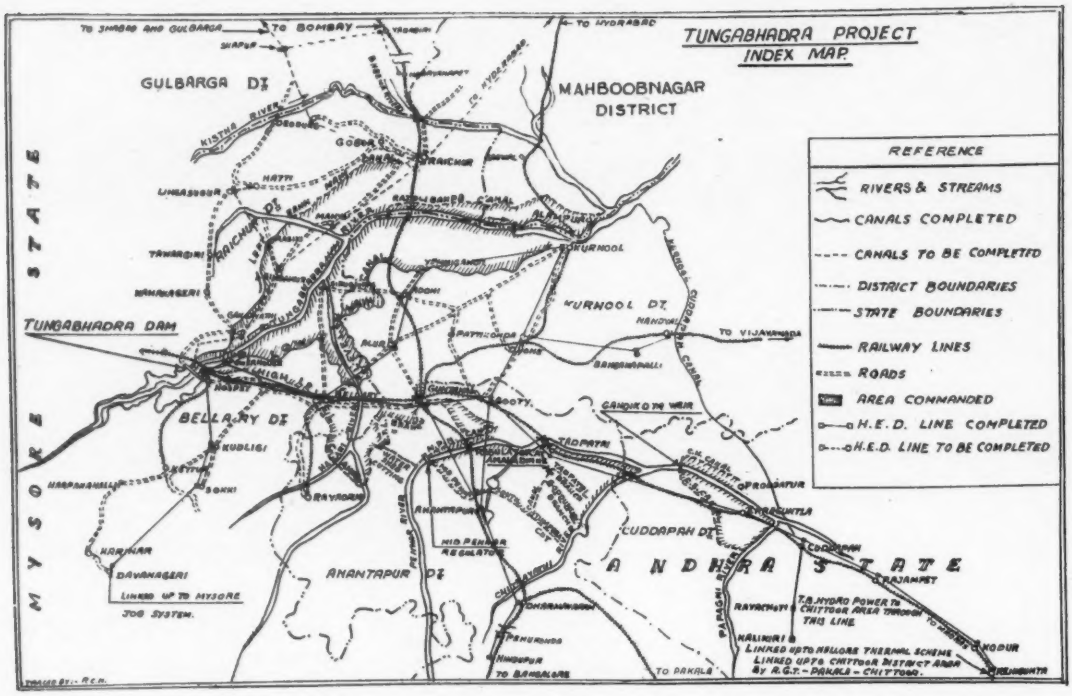
(*b*) *Low Level Canal*:—The Low Level Canal starts from the regulator mentioned above and runs 203 miles at the end of which Kurnool branch canal starts and runs 30 miles. This canal runs in Bellary and Kurnool districts. The Low Level Canal till about 10th mile crosses high rock ridges and deep valleys in close succession by deep rock cuts and high embankments. Construction of the Canal between 4th and 6th miles is spectacular and calls for great engineering skill. Here the Canal after skirting round the hills with side walling on the left for nearly a mile along the slope of a hill, crosses

River diversion works.

two deep ravines by means of concrete viaducts. Then the Canal pierces through a rocky ridge by a tunnel, 1106 feet long. The entire Canal is taken as contour canal. The entire country through which the canal travels being series of ridges and valleys, there are too many cross drainage works and are varied to a great extent ranging from a hume pipe culvert to a R. C. aqueduct. The biggest such cross masonry works is aqueduct across Hagari



Inauguration of Shutter Manufacturing Factory by Honourable Prime Minister of India, Sri Jawaharlal Nehru.



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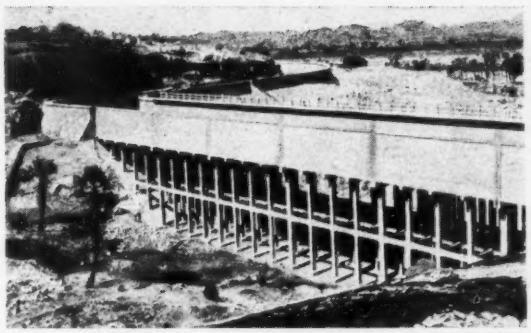
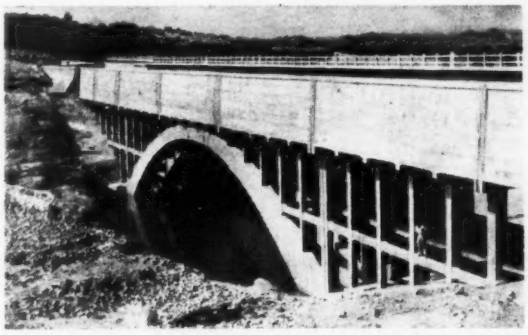


Side walling and trough vaiduct across 1st valley between 4th and 5th mile.

river between mile 75/0 to 76/0 of Low Level Canal. This aqueduct consists of twin troughs 12′-0″ wide each and 9′-2″ high. The troughs are carried on masonry piers resting on hexagonal wells sunk 25 feet deep in sandy river bed. The drainage vents are 58 of 35′-0″ span each and discharges 85,000 cusecs. This aqueduct measuring between abutments 2827 feet is the biggest in South India. Irrigation under this Low Level Canal starts from 12th mile. As many as 22 major distributaries and 115 minor distributaries take off from this canal to irrigate 2.5 lakhs of acres out of gross commanded area of 8.6 lakhs acres. Total cost of this Low Level Canal scheme is Rs. 13.13 crores.



Trough vaiduct across 2nd valley between 4th and 5th miles.

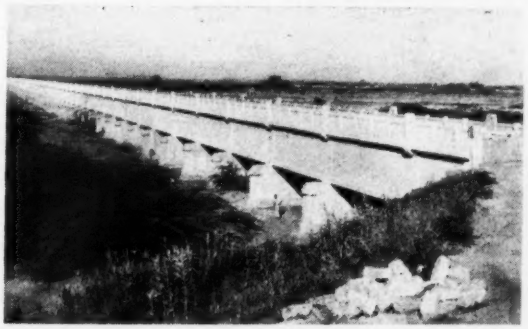
High Level Canal: The High Level Canal Scheme for which sluices have been built in the dam will take off at a level 35 feet higher than the Low Level Canal. The gross commanded area under this scheme is 13,43,430 acres, out of which only about 3.8 lakhs acres were proposed to be put under irrigation. The scope of this scheme is to take the canal upto 116th mile and thereafter cut through a water-shed called Uravakonda about 6 miles long and let down the water into Pennar river by dropping about 250 feet which will enable to develop power in future. Guntakal branch takes off at 116th mile to feed areas near about Guntakal. The Tungabhadra water that is dropped into Pennar as earlier mentioned will be picked up by a regulator across Pennar about 10 miles below, called Mid-Pennar Regulator. From this regulator 2 canals on either side take off. It is also proposed to have a wier with falling shutters at Gandikota with 2 canals on either side called Cuddapah north canal and Cuddapah south canal. The whole scheme is estimated to cost about Rs. 21.9 crores. This scheme is now

Canal piercing through a hill range by a tunnel.

split up into 2 stages by the Government of India, one for 13 crores and the other for 9 crores. Sanction is accorded to the first stage and works are being started.

Left Side Canal (Mysore Side)

The main canal is 127 miles long and mostly runs on contour upto 107th mile and on ridge beyond 107th mile. The country through which the canal passes is highly undulating with high ridges and deep valleys which involved heavy embankments and deep cuttings. For the first 19

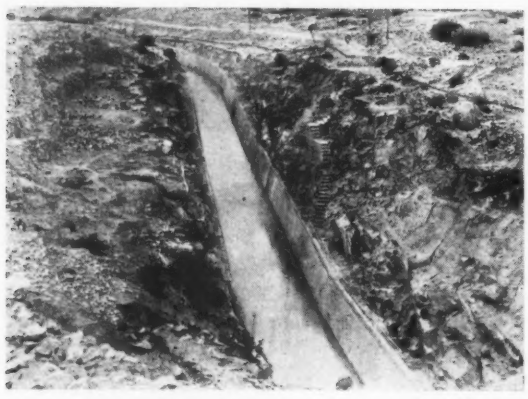


Hagari aqueduct.

miles the main canal runs through rugged terrain, replete with mute memories of the Vijayanagar Kingdom. During its course the canal cuts through three ranges of hills, the third range being pierced by a tunnel 3557 feet long and then enters open country. In this first 19 miles, the canal forms three reservoirs by constructing high masonry and composite dams in miles, 9, 14, and 15 of canal. These reservoirs afford scope for power generation. An interesting scheme is that the whole length of the canal is lined with concrete, Cuddapah slabs (etc.) and is one of the first of its kind in South India. This prevents seepage and increases the quantity of water effectively used for irrigation. The canal is designed to carry 7,000 cusecs out of which 3100 cusecs only will be utilised for irrigation and the rest will be again let down into the river after developing power at various stations. The canal is also designed for navigation from mile 24 to 127 *i.e.* upto Raichur. The total cost of this canal scheme is Rs. 22.88 crores. The salient details of the dam and canals are discussed in the following paragraphs.

Provision is made in the dam by providing sluices to supply water to the old irrigation channels which were taking off from anicuts on the up-stream of the dam. There are Raya and Basavanna channels on the right and Koregal channel on the left side. On the left side there is a provision for a High Level Canal with sill at +1585.00 of a capacity of 180 cusecs to feed High Level lands on left side.

As already mentioned earlier out of 8.6 lakh acres of gross commanded area under the Low Level Canal one-third is being brought under irrigation. This is mainly intended to irrigate dry crops, the entire area has been localised in blocks partly wet and partly dry. The introduction of irrigated dry is a novelty in this project when compared with the practice in other projects wherein water is supplied to wet cultivation which is mostly rice and sugar-cane. To facilitate quick development, channels for taking water to the fields are also being dug by the Government. The irrigation will extend to about 92,000 acres in the Mysore State and the rest of 1½ lakh acres in Andhra Pradesh. The present estimate of the acreage under different crops which will benefit by the Low Level Canal is as follows:—



A lined canal.

Irrigated cholam.

Dry cultivation (cotton, ground-nut, millets)	1,78,202	acres.
Wet cultivation (rice) ..	55,726	,,
Perennial (rice and sugar-cane).	15,330	,,

The annual food production estimated will be about 98,000 tons of food crops and 4,19,000 tons of commercial crops under this scheme after achieving full development.

The canal on left side irrigates only in Mysore State. Out of the total area of 10,80,000 acres commanded, it is proposed to irrigate 5,80,000 acres for the present. Raichur district which will benefit from this project at present grows dry crops and the following cropping pattern has been proposed.

Paddy (ABI)	50,000	acres.
Sugar-cane	15,000	,,
Khariff	2,00,000	,,
Rabi, jawar and other crops in rotation with khariff ..	2,00,000	,,
Rabi cotton.	75,000	,,
Perennial garden	5,000	,,
Two seasonal garden ..	25,000	,,
Tabi	10,000	,,
Total	5,80,000	,,

There will also be areas allotted for light and heavy seasonal garden crops. Besides an area of 85,000 acres will be under pasture and water will be made available for these as well.

The annual food production will be about 3,15,000 tons of food crops and 4,20,000 tons of commercial crops under this scheme after achieving full development.

Although this Tungabhadra Project Scheme is mainly intended for irrigation, provision is also made for generating power at the foot of the dam, utilising the head created by storage of water caused by the dam and also in the course of the irrigation canals where suitable drops occur. On right side the power house at the dam which is completed in all respects is producing power in two generating units of 9,000 kW. each. Provision for installing another two more generators of the same capacity is also made in the power house. Similarly the canal power house near the 14th mile of Power Canal near Hampi, is also producing power with two generating units of 9,000 kW. each with a provision for installing two more units of 9,000 kW. each at a later stage. The power developed by these two power houses is being utilised by the two States of Mysore and Andhra Pradesh.

The pattern of development of power on left side is also quite similar to the one on right side. Immediately below the dam five units generating 9,000 kW. each with a head of 60 feet have been planned and the execution of this scheme is at different stages now. There are another 3 more power development stations along the course of the canal at miles 9, 14 and 15 under contemplation.

GENERAL

The project in its wake has brought into play diverse economic, cultural and social interests since people from all parts of the country helped construction of the project. At the peak period of construction there was a total daily labour strength of about 70,000 workers both on right side and on left side put together. The labour and the staff employed for the construction work were provided with well laid colonies both at headworks and along canals. The colonies were well provided with suitable quarters with all modern facilities such as protected water supply, electricity, schools, marketing places, hospitals etc. There is a co-operative stores at the headworks on the right side with branches on the left side and along canals, run by the staff and labour to cater to their needs. The medical needs of labour and staff working along canal during peak period of construction were catered for by mobile medical units in addition to hospitals at important places. There is a separate Health Department attached to the project to look after the sanitary needs of all the colonies and to carry on anti-malarial operation.

The headworks and the canals form ideal places for tourists as this part of the country is replete with historic and mythological interests. Ruins of Hampi and the capital of the famous Vijayanagar empire is only 10 miles below the dam-site. Tourist facilities are available at headworks and Hospet.

Finally it is very interesting to visualise that this multi-purpose project across the river Tungabhadra with its tremendous potentialities of irrigation and power development undoubtedly revitalises the entire area on both sides of the river which was once a deserted and uninhabited stretch of land for miles together.

Well laid labour colony at Headworks.

FACTS AT A GLANCE

Dam & Appurtenant Works

1. *Location:*

E. Longitude.	76°-20′-10″	At Mallapuram village about 3 miles from Hospet town, Mysore State, acros Tungabhadra river.
N. Latitude.	15°-15′-49″	

2. *States concerned*: Mysore and Andhra Pradesh.

3. *Date of commencement of work*: February 1945.

4. *Date of completion*: 1959-60 Right side. 1963-64 Left side.

5. *Dam.*

(*a*) *Masonry Dam*:		
(*i*) Non-spillway section:	3412′	
(*ii*) Spillway section	2300′	
(*iii*) Average height above foundation level:	162′-0″	
(*iv*) Average height above river bed:	116′-0″	
(*v*) Width of road-way on top of dam:	22′-0″	
(*vi*) Width at base:	93.5′	
(*vii*) Lowest foundation level:	Plus 1478.00	
(*viii*) Sill of Spillway crest gate:	Plus 1613.00	
(*ix*) Full reservoir level:	Plus 1633.00	
(*x*) Maximum water level:	Plus 1633.00	
(*xi*) Top level of dam:	Plus 1640.00	
(*xii*) Size and Number of spillway gates:	33 Nos. (60′ × 20′ each).	
(*xiii*) Total excavation:		
(*a*) In rock.	12.5 million cubic feet.	
(*b*) In earth.	10.8 Million ,,	
(*xiv*) Total quantity of masonry (in dam portion):	32 million cubic feet.	
(*xv*) Total quantity of concrete (in dam portion).	1.7 million cubic feet.	
(*b*) *Composite Dam*:		
Length:	1794′	
Height:	70′	
(*c*) *Earthen Dam*:		
Length:	500′	
Height:	30′	
Total quantity in earth and composite dams:		
(*i*) Masonry:	1.2 M.Cft.	
(*ii*) Earth-work:	5.92 M.Cft.	

6. *Reservoir*:

Catchment area:	10,880 sq. miles.
Gross storage capacity:	133 T. M. Cft.
Live storage capacity:	130.7 T. M. Cft.
Reservoir water spread:	146 sq. miles.
Length of reservoir:	50 miles.
Estimated annual yield (Average):	407.1 T. M. Cft.
Maximum flood discharge:	3,30,000 cusecs.
Number of villages to be sub-merged:	89
Population to be displaced:	54,452.

7. *Sluices (Right side)*:

	No.	*Size.*	*Sill level.*
High level sluices:	10	6′ × 12′	plus 1585.00
24″ diameter pipe:	1	24″ diameter	plus 1579.00
Sluice for existing irrigation:	1	6′ × 12′	plus 1550.00
H. E. turbine pipes both for power and irrigation:	4	11′ diameter	plus 1550.00
River Sluices:	2	6′ × 12′	plus 1550.00

8. *Sluices (Left side)*

High level sluices:	4	4′ × 5′	plus 1585.00
Irrigation & H. E. sluices:	10	8′-9″ × 11′-6″	plus 1550.00
24″ diameter pipe:	1	24″ diameter	plus 1579.00

9. Cost of the dam and appurtenant works: Rs. 16.96 crores.

Canals

Particulars	*Right side* — *Low Level Canal*	*Right side* — *High Level Canal*	*Left side*
(1)	(2)	(3)	(4)
10. *Canals*:			
Length:	217 miles.	122 miles.	127 miles.
Discharge: (For power & irrigation):	2,500cusecs	4,000 c/s	7,000 c/s
(for irrigation only)	1,800 c/s	4,000 ,,	3,100 ,,
Qty. of earth-work excavation in main canal.	8,50,000 units	5,70,000 units.	12,16,000 units.
Bed width:	72′-0″	65′-0″	84′-0″
F. S. Depth.	10′-5″	12′-0″	14′-0″
Velocity (average).	3.0′/second	4.5′/second.	4.5′/second.
Fall.	1 in 10,560	1 in 10,000	1 in 10,000
11. *Masonry Works:*:			
(*a*) Head sluice and direct pipe sluices for distributaries.	125 Nos.	24 Nos.	100 Nos.
(*b*) Regulators.	15 ,,	9 ,,	6 ,,
(*c*) Aqueducts.	35 ,,	24 ,,	19 ,,
(*d*) Under-Tunnels.	145 ,,	115 ,,	64 ,,
(*e*) Super-passage & Syphones.	3 ,,	11 ,,	9 ,,
(*f*) Railway bridges.	3 ,,	6 ,,	1 ,,
(*g*) "B" class bridges.	14 ,,	17 ,,	7 ,,
(*h*) "L" class bridges.	90 ,,	49 ,,	41 ,,
(*i*) Foot bridges.	4 ,,	6 ,,	2 ,,
(*j*) Escapes.	10 ,,	5 ,,	6 ,,
(*k*) Other cross masonry works, such as in-lets, out-lets etc.	116 ,,	5 ,,	7 ,,
Total	560 ,,	271 ,,	262 ,,
12. Gross commanded area.	8,60,000 arc.	13,43,430 a/c.	10,80,000 a/c.
Cultivable commanded area.	7,50,000 ,,	....	8,00,000 ,,
13. Irrigable area proposed.	2,50,000 ,,	3,88,300 ,,	5,80,000 ,,
14. Cost of the canals.	13.13 crores	21.90 crs..	22.88 crs.
15. Annual food production.	98,000 Tons	1,60,000 tons.	3,15,000 tons.
16. Annual production of commercial crops.	4,19,000 ,,	79,000 ,,	4,20,000 ,,

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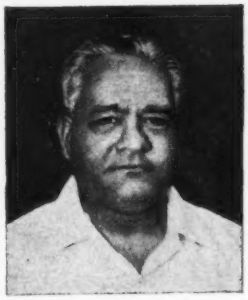

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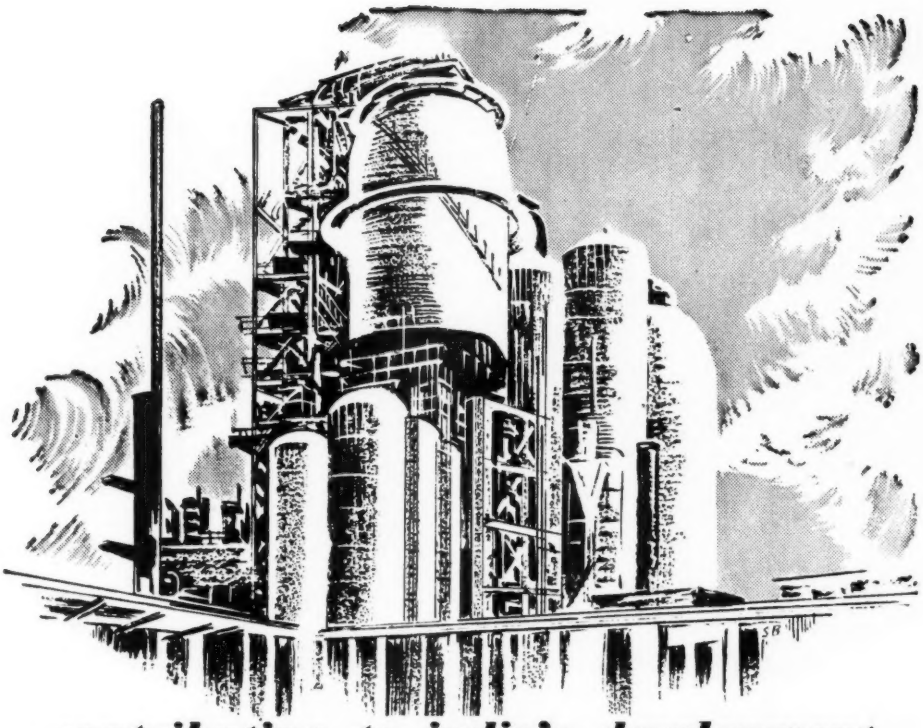

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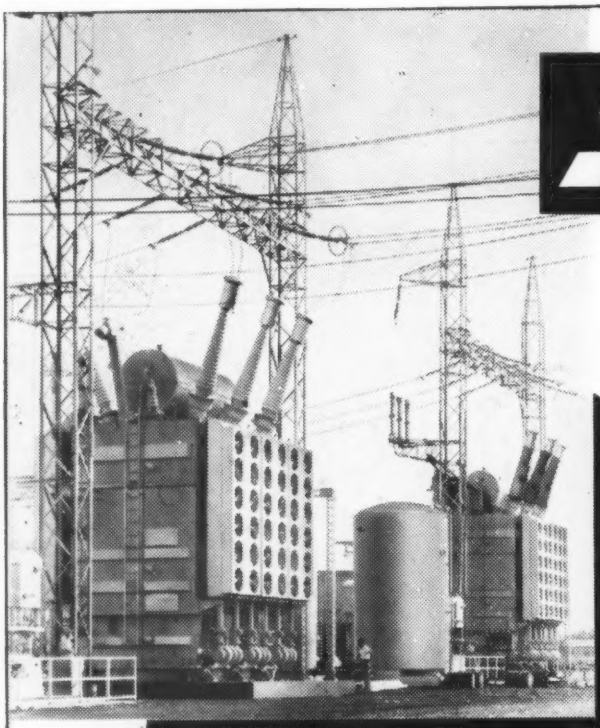

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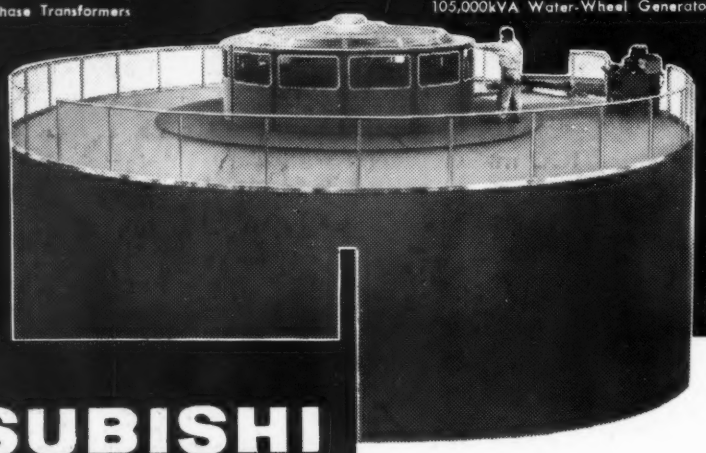

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